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Growing seed

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PHYTOREMEDIATION OF WASTEWATER AND EFFLUENTS USING AQUATIC WEEDS

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Contamination of the aquatic environment by the heavy metals has become a serious concern in the developing world. Heavy metals unlike organic pollutants are the persistent in nature, therefore, tends to accumulate in the different components of the environment. These metals are released from a variety of sources such as mining, urban sewage, smelters, tanneries, textile industry and chemical industry. There are more than 300 distilleries in India, which produces approx. 3.5×10^{15} litres of waste effluent annually (AIDA, 2004) loaded with high BOD, COD values, phenolic, sulphates, phosphates, and various potentially toxic trace elements (Kumar and Chandra, 2004).29000 million litres sewage is produced daily in India from class I and class II cities; while the remediation capacity of sewage treatment plants in our country is only 6000-7000 million litres per day.

In India we are following only primary treatment for the remediation of wastewater, in some cases secondary treatment. Textile wastewater also contains substantial pollution loads which increase the Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended solids (TSS), Total Dissolved Solids (TDS) and heavy metals. Large areas of agricultural soils and aquatic environment are contaminated by trace element that mainly originates either from geogenic activities or agronomic practices, industrial emissions, or the application of waste effluents/sewage sludge.

Sewage water and its impact on water bodies

Sewage is human habitat base liquid waste, Sludge produced at time of treatment which causes

- ✓ Heavy metal accumulation
- ✓ Odour
- ✓ Exposure to pathogens
- ✓ Mosquito breeding in water bodies

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At present 450 cities in India generate 17x106 m^3 of raw sewage per day Production of sludge is estimated to be around 1200 tonnes per day, potentiality is 4000 tonnes per day. Delhi city produces 600 million litres of waste water per day, 175 million litres untreated Five major sewage treatment plants in Delhi produce 1200 million litres treated effluents per day-used to irrigated crop.

Table No. 1. Potential contaminants in wastewater

Contaminant	Concern
Pathogens	Human and soil health.
Nitrates	Groundwater pollution
Organics (chlorinated hydrocarbon pesticides), polychlorinated biphennyls (PCBs)	Deterioration of soil health Health hazard if directly ingested by animals.
Heavy metals:	
Copper, zinc, nickel and Lead	Accumulation in topsoil; toxic to plants at high levels.
Cadmium	taken up by plant and accumulates in leafy material
Mercury, chromium, selenium, arsenic	Little concern unless present in extremely high amounts.

Zinc (Zn) is considered as a serious environmental pollutant because of its non-degradability when discharged into a water body (Ineris, 2005). When present at elevated concentrations in aquatic systems (lakes, ponds, aqueous streams, etc.), Zn causes a variety of environmental problems, including loss of vegetation, groundwater contamination and metal toxicity in the food chain.

Why metals are toxic

- Oxidative stress: Redox active transition metals (e.g. Fe^{2+}, Cu^{2+}) produce free radicals
- Replace other essential metals in pigments and enzymes
- Some metal ions (Hg^{2+}, Cu^{2+}) react to thiol groups to interfere protein structure and functions
- (a) Land treatment Some metals occur as radioactive isotopes (^{238}U,^{137}Cs etc.) to pose health risks.

The conventional methods for treating metal-contaminated waters are ions exchange, coagulation– flocculation, chemical precipitation and adsorption (Lenoble, 2003). These techniques are generally expensive especially if large volumes, low metal concentration and high standard of cleaning are required (Miretzky *et al.*, 2004). In addition, these methods usually generate by-products (sludge, metal-rich waste, etc.) dangerous to our environment.

(a) Land treatment

(b) Thermal treatment

(c) Ground water extraction and treatment

(d) Chemical extraction

(e) Ion exchange

(f) Adsorption

Phytoremediation

There is a considerable potential for adopting other methods which show effectiveness and economic advantages. Phytoremediation has recently gained importance because of its cost-effectiveness, long-term applicability and ecological aspect (Weiss *et al.*,2006; Rai, 2008). This technology is based on the ability of plants to absorb and accumulate metal contaminants in their tissues and eliminate high amount of these elements from water or groundwater. The process of phytoremediation requires metal absorption by roots and its translocation to shoots and leaves. The bio-removal process using aquatic plants contains two uptake processes: biosorption which is an initial fast, reversible, metal-binding process and bioaccumulation, a slow, irreversible, ion-sequestration step (Keskinkan *et al.*, 2003).

A successful bio-sorption of Cd, Ni, Zn, Pb and Cu by dead biomass of aquatic macrophytes through ion exchange (Miretzky *et al.*, 2006), underlined a wide perspective for investigating bio-sorption from multi-metal solutions and studying interactive effects of other metal ions on ion-exchange process. Low cost and relatively higher efficiency of heavy metal removal from diluted solutions are among the leading advantages of bio-sorption, which could be easily adopted by developing countries like India for recycling/ treatment of heavy metal contaminated wastewater (Jang *et al.*, 2005).

Phytoremediation used for removing heavy metals and other pollutants by AMATS (aquatic macrophytes treatment systems) is a well-established environmental protective technique. The most common aquatic macrophytes being employed in wastewater treatment are water hyacinth (*Eichhorniacrassipes*), penny wort, water lettuce, water ferns and duck

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weeds. Phytoremediation is use of green plants to remove pollutants from the environment or render them harmless. This concept has emerged from a broader philosophy of Bioremediation where besides plants, soil microorganisms are also used for amelioration of organic and inorganic contaminants. The presence of other aquatic photosynthetic autotrophs can deplete dissolved CO_2 in water during the period of high photosynthetic activity. This increases dissolved oxygen in the wastewater thus resulting in increased water pH.

Different approaches of phytoremediation

1. **Phytoextraction:** Accumulation of metals in shoot tissues followed by harvesting
2. **Phytodegradation:** Use of plants and microbs to degrade organic pollutants
3. **Rhizofiltration:** Use of plant roots to absorb and adsorb the heavy metals form water bodies
4. **Phytostabilization:** Reduction in leaching, runoff, soil erosion and bioavailability of heavy metals
5. **Phytovolatilization:** Use of plants to volatilize heavy metals

Aquatic plants and phytoremediation of water bodies

- Aquatic plants are chosen for absorb particular nutrient and to remove pathogens, metals and other contaminants from wastewater.
- Aquatic plants have been shown to be very effective as a secondary or tertiary state for water treatment and nutrient removal.

Table No. 2. Functions of plants in aquatic treatment

Plant parts	Functions
Roots and/or stem in water Column	Uptake of pollutants
	Surfaces on which bacteria grow
	Media for filtration and adsorption of solids
Stem and/or leaves at or above water surface	Absorbed sunlight, thus can prevent growth of suspended algae
	Reduce transfer of gases and heat between atmosphere and water

Common aquatic weeds used for phytoremediation

- Water hyacinth [*Eichhorniacrassipes (Mart.) Solms*]
- Penny wort (*Hydrocotylebonariensis*)

- Water lettuce (*Pistia stratiotes L.*)
- Water fern (*SalviniaauriculataAublet*)
- Duck weed (*Lemnagibba L.*)

Water hyacinth as a major bioremediator

Water hyacinth:-

B. N.-*Eichhorniacrassipes (Mart.) Solms*

Family- Pontederiaceae

Origin- Tropical South America

It is a most reproductive plants on earth thus it is considered the world's worst aquatic plant. Water hyacinth has the unique property to accumulate heavy metals such as cadmium, copper, lead and zinc in the root tissue of the plant. In terms of bacterial reduction by water hyacinth-based systems, two theories exist. First, bacteria are trapped in the rhizosphere of the macrophytes with TSS, and second, water hyacinth may secrete chemical substances having bacteriostatic effects. The extensive removal of heavy metals by water hyacinth may be due to extensive adventitious root system, which absorbs these toxic substances from wastewaters (Mandi, 1994). Water hyacinth forms dense mats on the water surface of the non-saline part of the estuary and this is much common during the wet season.

Table No. 3. Characteristics of a typical wastewater: (Mahmood *et al.*, 2005)

Sample No.	**Parameters**	**Range in wastewater (mg/L)**
1	pH	5.5-10.5
2	COD	350-700
3	BOD	150-300
4	Total dissolved salts	1500-2200
5	Total suspended salts	200-1100
6	Sulphides	5-20
7	Chlorides	200-500
8	Chromium	2-5
9	Zinc	3-6
10	Copper	2-6
11	Oil and grease	10-50
12	Sulphates	500-700
13	Sodium	400-600

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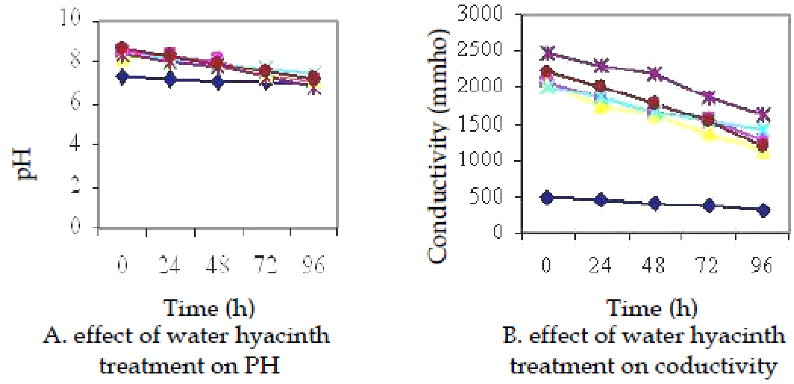

Figure 1. Effect of water hyacinth on pH and conductivity of wastewater (Mahmood *et al.*, 2005)

Mahmood and his co-workers collected effluents from five different textile industries viz. (1) M/S asma dying and printing industries, (2) Cebee industries, (3) Comfort wear knit, (4) Al-Saeed dying nad printing industries and (5) Kamran textiles. And reported the effect of water hyacinth treatment of wastewater in relation to pH and conductivity and they reported a considerable reduction in the conductivity and pH of the wastewater. The maximum reduction in the conductivity was obtained for wastes from CEBEE Textile Industries (55.71%). It can be interpreted that the reduction in pH and conductivity might be due to absorption of pollutants by plant (Figure 1) (Mahmood *et al.*, 2005).

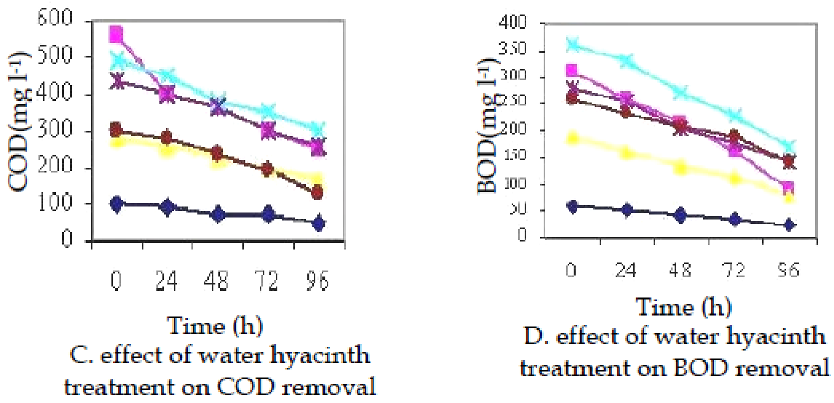

Figure 2. Effect of water hyacinth treatment on BOD and COD of wastewater

Water hyacinth treatment shows a significant reduction in biological oxygen demand (BOD) and chemical oxygen demand (COD) which ranging from 40-70 % is very encouraging performance for any kind of industrial waste after only 96 hours of treatment. The presence of plants in wastewater can deplete dissolved CO_2 during the period of high

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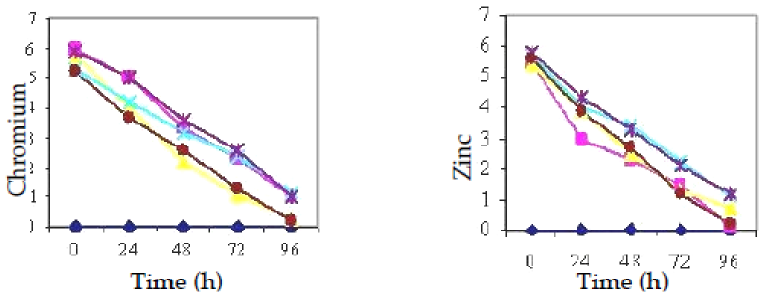
photosynthetic activity. This photo-synthetic activity increases the dissolved oxygen of water, thus creating aerobic conditions in wastewater which favor the aerobic bacterial activity to reduce the BOD and COD. The maximum reduction (70%) was obtained for wastewater collected from CEBEE textiles (Figure 2).



E. effect of water hyacinth treatment on chromium removal

F. effect of water hyacinth treatment on zinc removal

Figure 3. Effect of water hyacinth treatment on Chromium and Zinc concentration in wastewater (Mahmood *et al.*, 2005)

Water hyacinth has tremendous potential to remove heavy metals from wastewater, treatment of textile wastes with water hyacinth resulted 78.30-94.78% reduction in chromium, 79.34-96.88 % in zinc and 78.30-94.44 % reduction in copper. The maximum reduction of chromium and zinc occurred from Al-Saeed Textiles while the maximum reduction for copper was noted in the wastewater from Cebee Textiles (Figure 3).

Tripathi and his co-workers reported the per cent removal of heavy metals at different concentrations of these metals and they reported that metal removal percentages were highest at 2 mg l^{1-} for all the three macrophytes for most of the times. Removal percentage decreases for the metals at 5.0 mg l^{1-} with few exceptions. The heavy metals removed by E. crassipes were very high and ranged between 77% and 95% in 12 days incubation period (Table 4). The highest removal percentage at 1.0 mg l^{1-} was shown by E. crassipes (92) followed by P. stratiotes (91) for Zn whereas this was increased at 2.0 mg l^{1-} and it was maximum for E. crassipes and P. stratiotes as 95% for Fe. Removal efficiencies reached highest at 2.0 mg L^{-1} for all the metals except Cu which has shown slightly increased removal percentage at 5.0 mg L^{-1}

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Table No. 4. Removal of heavy metals through three aquatic macrophytes (Triphathi *et al.*, 2008)

Heavy metals	Concentrations (mg l^{-1})	% Removal		
		Pistia stratoites	*Spirodela polyrrhiza*	Eichhornia cressipes
Fe	1	87	83.5	85.7
	2	95	81	90.1
	5	90	77.5	78.6
Cu	1	96	91	95
	2	87	83	89
	5	88	76	86
Cd	1	78	63	81
	2	82	71	85
	5	70	65	77
Cr	1	81	83	85
	2	75	75	89
	5	70	62	81
Zn	1	90	90	92
	2	92	92	95
	5	82	82	85

Table No. 5. Heavy metal concentration in macrophytes and impacts on biochemical parameters (Tripathi *et al.*, 2008)

	Concentration (mg/l)	Chlorophyll (mg g^{-1})	Protein (mg g^{-1})	Sugar (mg g^{-1})
Eichhornia crassipes				
Leaves	0	10.31	113.3	40.12
	1	8.67	98.4	28.5
	2	6.2	81	20.4
	5	4.17	65.25	16.3
Roots	0	—	77.26	13.36
	1	—	67.34	8.16
	2	—	61.24	7.26
	5	—	54.23	2.16
Spirodela polyrrhiza				
Leaves	0	2.67	51.42	26.1
	1	2.52	43.71	17.2
	2	2.1	27.11	10.5
	5	1.6	24.33	6.8
Roots	0	—	16.8	9.8
	1	—	11.2	6.3
	2	—	9.3	2.1
	5	—	4.2	1.7
Pistia stratiotes				
Leaves	0	7.12	67	11.26
	1	5.63	52	9.8
	2	4.12	48	6.5
	5	3.06	21	3.3
Roots	0	—	21.3	9.7
	1	—	17.2	6.6
	2	—	14.5	5.4
	5	—	6.7	3.12

Heavy metal accumulation in aquatic macrophytes is known to produce significant physiological and biochemical responses towards the growth of roots, stems and leaves (Shankers *et al.*, 2005). These parameters decreased in plant tissues after 15days incubation period. Chlorophyll content decrease from10.31 mg g^{-1} to 4.17 mg g^{-1} in E. crassipes, 2.67 mg g^{-1} to1.6 in P. stratiotes and 7.12 to 3.06 mg g^{-1} in S. polyrrhiza. The reduction of chlorophyll content in macro phytesmay be attributed to inhibition of chlorophyll synthesis which results in the loss of photosynthetic activity The decrease in sugar content may be associated with reduced photochemical activities and chlorophyll formation. Loss of sugar formationmay also be due to the conversion of sugar into energywhen the plants were stressed (Table 5).

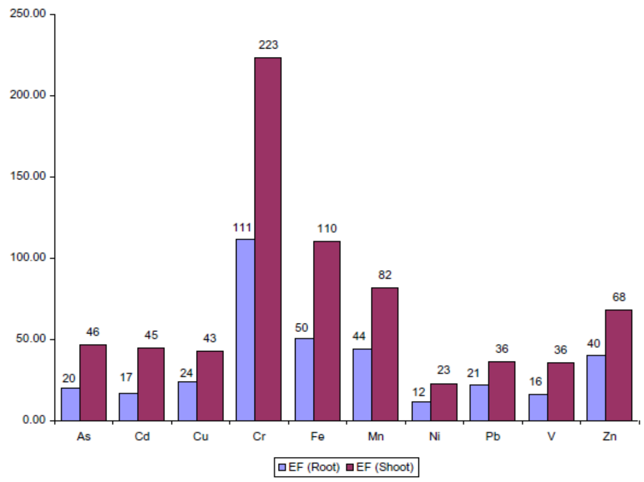


Figure 4. Enrichment factor of the metals from the coastal to root and shoot of water hyacinth (Bamidele *et al.*, 2009)

Bamidele and his co-workers reported the enrichment factor of the water hyacinth which is the measurement of the degree of metal transfer from water to the plant roots and shoots for different metals. They reported that the degree of enrichment of the shoot is higher than that of the root for the ten metals which indicates that the metals are transferred into the upper part of the plant (Figure 4). The least EF observed in the study was 12 which corresponded to Ni metal transfer to the plant root. Cr is the most transferred metal into both the root and the shoot followed by Fe, Mn and Zn in the decreasing order. phytoextraction of metals depends on factors such as the degree of site contamination, plant's ability to intercept, absorb and accumulate metals in shoots, metal availability for uptake into roots governed by its dissolution into aqueous phase and ultimately the interaction between the plant habitat.

However, the high EF indicates the plant's ability to intercept, absorb and accumulate metals in both its root and shoot; the high bioavailability of the metals that are already in aqueous phase for easy uptake by the plant and favourable interaction between the metals, the plant and the aquatic habitat where the plant grows. The uptake rate of the plant for metals was predicted at approximately 0.5 µg/day using the predictive mathematical model which relates transpiration stream concentration factor (TSCF) (Figure 4).

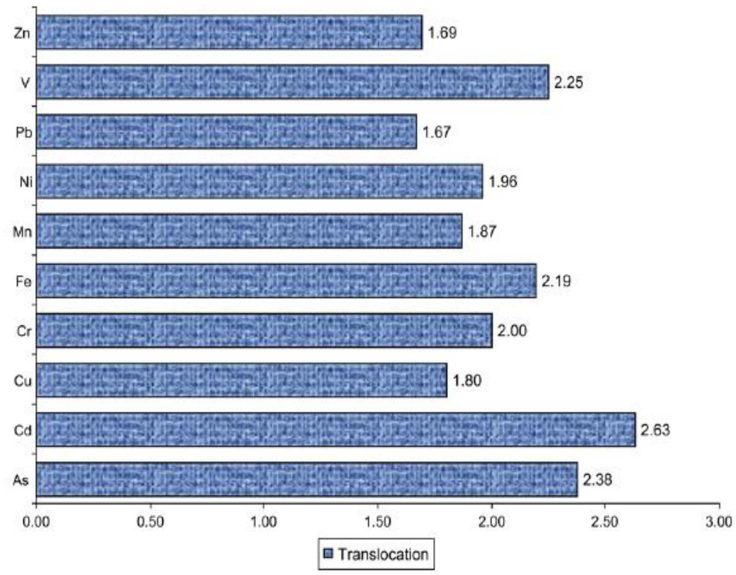
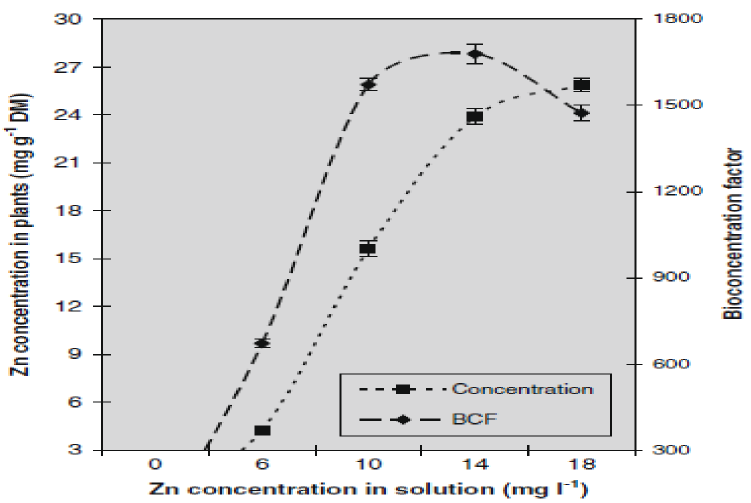


Figure 5. Translocation of metals from root to shoot of water hyacinth (Bamidele *et al.*, 2009)

Translocation of the metals from the root to the plant shoots which must be above 1 if the plant has to be an effective phytoremediator. The translocation of the metals into the shoot is higher than that into the root which implies that the plant has a high capacity to absorb the metals in the stalk and the leaves than the root. The translocation of Cd is ranked highest followed by those of As, V, Fe, Cr in the decreasing order (Figure 5).



Graph 1. Zinc concentration in solution and its accumulation in *Lemnagibba* (Khellaf and Zerdaoui, 2009)

Khellaf and Zerdaoui reportedThe Zn concentration in L. gibba increased with increasing initial concentration in the Coïc solution. The metal amount accumulated in duckweed biomass was 4.23, 15.62, 23.88 and 25.81 mg g^{-1} DM when the medium was supplied with 6.30, 9.92, 14.23 and 17.57 mg g^{-1} of Zn, respectively (Graph 1). To quantify metal accumulation in plant biomass, the bio concentration factor (BCF) is more significant than the amount accumulated in plants since it provides an index of the ability of the plants to accumulate metal element with respect to the element concentration in water.

Conclusions

- The heavy metals show a greater affinity towards bioaccumulation by aquatic weeds, which lead to filtration of metallic contaminants from wastewater.
- The maintaining of proper density of macrophytes in the water bodies by way of harvesting followed by disposal may regulate heavy metal contamination of water bodies without introducing any foreign chemicals.
- *Eichhorniacrassipes* has high affinity to accumulate metals in both root and shoot in a high degree and also to be capable of transferring the metals absorbed into the shoot to give higher translocation factors.
- Plants having large biomass on the water course with broad leaves and not consumed by animal/human being could serve as an effective phytoremediation.

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ROLE OF MICROBES IN THE SERVICE OF HUMANITY

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Microbes were the first form of life, originating almost four billion years ago and they will continue to inhabit our planet even long after disappearance of humans and other life forms. The invisible world of the microbes represents far greater evolutionary and metabolic diversity than the visible organisms familiar to us. They are the supreme waste recyclers and regenerators of the planet. Microbes are ubiquitous, and their activities sustain and influence the quality of all life on earth. Although we humans consider ourselves to be the stewards of planetary health, microbes are much more powerful agents, central actors and key stakeholders of influence, regulation and change of planetary activities and biological evolution. Microbes and their activities have pervasive, remarkably profound and generally positive effects on the functioning, and thus health and well being of human beings, the whole of the biological world, and indeed the entire surface of the planet and its atmosphere. Collectively and to a significant extent in partnership with the sun, they are the life support system of the biosphere. Plant associated microbes mediate acquisition of essential minerals including nitrogen (indeed without microbial mediated nitrogen fixation, there would not have been enough biomass production by plant, primary producers for the proliferation and evolution of animal consumers), protect against infections and produce hormone like compounds that promote plant growth. Some microbes carried by plants are toxic to animals and hence function as a plant defence against predators. The ability to recognize new opportunities of microbial activities in a timely manner, to accurately assess benefits and possible risks, and to take evidence based decisions on actions needed to facilitate their exploitation, is essential for knowledge based, bio-centric economies to be competitive and to progress significantly towards sustainable practices.

The concept of effective microorganisms

A unique approach for controlling the soil micro flora and for maximizing their beneficial effects has been developed by Professor Teruo Higa at University of Ryukyus in

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Okinawa, Japan who is the innovator of the concept of effective microorganisms, a promising new technology. EM consists of mixed cultures of naturally occurring beneficial microorganisms that can be applied as inoculants to increase the microbial diversity of soils and plants. Research has shown that these EM cultures can improve soil health; growth, yield and quality of crops (Higa and Wididana, 1991). There is evidence that supports several theories concerning its action including a) suppression of plant pathogens and diseases b) enhanced nutrient availability c) stimulated plant growth (*i.e.* auxin mediated effects) and d) improved root surface-rhizosphere relationships (Higa and Wididana, 1991).

Using EM to improve soil health and performance

EM works by getting the natural processes to function, the way nature intended by stimulating biological activity in the soil. Using EM will not only add to the microbial population but also stimulate resident microbes. This stimulation can lead to increase the nitrogen fixation capacity directly through the increase of N fixing bacteria, and indirectly by increasing growth and activity of mycorrhiza, other fungus and earthworm. EM can enhance growth and improve soil health through:

- Enhancing fertiliser inputs
- Converting organic matter to plant nutrients
- Decomposing organic residues
- Recycling soil nutrients
- Breaking down fertiliser compounds
- Improving root structures
- Breaking down pollutants in the soil
- Increasing earthworm numbers
- Reducing compaction issues
- Building soil humus

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Table No. 1. The role of microorganism in organic agriculture

Sl. No.	Group of microorganism	Kind and name
1.	Can fix Nitrogen a. Free living b. Living with other plants	a. Blue green algae (*Anabaena*, *Nostoc*); Bacteria (*Azotobacter*, *Azospirillum*) b. Blue green algae (*Azolla-Anabaena*); Bacteria (*Rhizobium* sp.)
2.	Solubilise Phosphate a. Free living b. Symbiosis	a. Bacteria (*Bacillus* sp., *Pseudomonas* sp.); Fungus (*Aspergillus* sp., *Penicillium* sp., *Fusarium oxysporum*) b. Fungus (Mycorrhizal fungi): Vesicular Arbuscular Mycorrhiza
3.	Decompose organic matter	*Trichoderma viride*, *Chaetomium abuanse*, *Myrothecium roridum*, *Aspergillus niger*, *Cellulomonas* sp., *Cytophaga* sp., *Bacillus* sp.
4.	Protect from insect pests	Virus (DNA viruses, RNA viruses); Bacteria (*Bacillus thuringiensis*); Fungus (*Entomophthora*, *Masospora*); Protozoa (*Nosema Locstae*, *N. bombycis*); Nematode (*Neosplectona*, *Carpocasae*)
5.	Can control weeds	*Cercospora rodmanoo*, *Celletortrichum glocoaporipeds*, *Punccinia chroudrillina*
6.	Antibiotic production a. Fungus b. Bacteria c. Insects	a. Cyclohexinide (*Streptomyces griseus*) Blasticidins (*S. griseochromogenes*) Polyozins (*S. cacaoi*) b. Streptomycin (*S. griseus*), Oxytetraccycline (*S. viridifaciens*) c. Tetranctin (*S. aureus*)
7.	Food for people and animals	Algae and Plankton (*Sprieulina*, *Nostoc*); Yeast; Mushroom (*Fusarium graminearum*, *Choetomium cellulolyticum*)

Microbes and biotechnology

Microorganisms are mostly microscopic small creatures which are placed in different groups such as bacteria, fungi, protozoa, micro algae and viruses. These organisms live in soil, water, food, animal intestines and other different environmental conditions.

a. Men use some of microbial diversity in the production of fermented foods such as bread, yogurt, and cheese.

b. Some soil microbes release nitrogen that plants need for growth and emit gases that maintain the critical composition of the earth's atmosphere.

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c. Other microbes challenge the food supply by causing yield reducing diseases in food producing plants and animals.

d. In our bodies, different microbes help to digest food, ward off invasive organisms, and engage in skirmishing and pitching battles with the human immune system in give and take of the natural disease process.

e. Microbial biotechnology is an important area that promotes advances in food safety, food security; value added products, human nutrition and functional foods, plant and animal protection, and overall fundamental research in the agricultural sciences.

f. Microbial biotechnology, enabled by genome studies, will lead to breakthroughs such as improved vaccines and better disease diagnostic tools, improved microbial agents for biological control of plant and animal pests, modifications of plant and animal pathogens for reduced virulence, development of new industrial catalysts and fermentation organisms, and development of new microbial agents for bioremediation of soil and water contaminated by agricultural runoff.

Microbial biotechnology and its applications in agriculture

a. Natural fermentation
b. Bio-fertilizers
c. Bio-pesticides
d. Bio-herbicides
e. Bio-insecticides

Now increasing attention has been paid to the development of sustainable agriculture in which the high productivities of plants and animals are ensured using their natural adaptive potentials, with a minimal disturbance of the environment (Noble & Ruaysoongnern, 2010). It is our view that the most promising strategy to reach this goal is to substitute hazardous agrochemicals (mineral fertilizers, pesticides *etc*.) with environment friendly preparations of symbiotic microbes, which could improve the nutrition of crops and livestock, as well as their protection from biotic (pathogens, pests) and abiotic (including pollution and climatic change) stresses (Yang *et al*., 2009). At present, a wide spectrum of preparations of diverse microbial species may be used to enhance crop production (Andrews *et al*., 2010).

Conclusions

Global food demand is increasing rapidly especially more in developing nations where crop lands and resources hardly contribute to an efficient crop production needed to meet such an urgent demand for food. There is an urgent need to intensify agricultural production in a sustainable manner through the use of efficient agro-ecosystems which consider the entire bio-chemical diversity and their potential to mitigate the adverse impact of low soil fertility, abiotic stress, pathogens and pests (Timmusk *et al*., 2017). In this context, global food security issue will foster reliance on innovation, development, and delivery of technologies that lead to increased food production while ensuring sustainable intensification of agriculture. Microbial technology through the integration of beneficial microbes and micro biome interactions may represent a promising sustainable solution to improve agricultural production (Timmusk *et al*., 2017). For instance, advances in genomic, post genomic, biochemistry, ecology and symbiotic interactions of beneficial microbial strains have led to the development and commercialization of efficacious microbial products (bio-fertilizers, bio-stimulants, bio-pesticides, bio-herbicides and plant growth promoters *etc*.) with proven success to improve crops' yield and adaptation to environmental changes, and inputs of carbon and energy (Lindemann *et al*., 2016; Umesha *et al*., 2018).

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MOBILE APPS IN AGRICULTURE: A BOON FOR FARMERS

Article Id: AL202037

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Agriculture plays a vital role in the Indian economy with over 58 per cent of rural households depending on agriculture as their principal means of livelihood. Agriculture, along with fisheries and forestry alone contributes 17.32 % of the Gross Domestic Product (GDP) in India. The challenging task for farmers is information management mainly in terms of the amount of data and the complexity of processes in precision farming. To meet this pressing challenges in this digital era, technology driven smart mobile apps cater to the needs of the farmers.

The digital boom in the recent past has made India one of the largest users of internet and mobile telephony in the global map. India is 2nd largest user of Internet next to China with 560 million internet subscribers in 2018 (IAMAI, 2019). Rural Internet penetration has increased from 9 per cent in 2015 to 25 percent in 2018 with estimated 251 million internet users. India being a young country with around 200 million rural youths i.e 41 % of total population in India, are motivated and attracted professionally to agriculture and allied fields. And therefore, there is significant positive indication of digital transformation among the rural masses predominantly represented by rural youth. According to 'The Rising Connected Consumer in Rural India', a study by the Boston Consulting Group, up to 300 million Indian consumers are expected to be online by 2020. More than half of the new Internet users are expected to come from rural communities. Cheaper mobile handsets, spread of wireless data networks, and evolving consumer preferences will all drive rural penetration and usage (BCG, 2016).

Information and Communication Technologies (ICT) has seen a powerful role in daily life of farmers.ICT in agriculture is an emerging field focusing on the agricultural development and rural development in India. Introduction of ICT in Indian agriculture enables the dissemination of requisite information at the right time. ICT tools like Mobile Apps serve as smart Decision Support Tools (DST) and are designed to help users make more effective decisions by leading them through clear decision stages and presenting the likelihood of various outcomes resulting from different options. The modern day's mobile apps are software programs designed to run on smart phones, tablets and other devices. The application software on a mobile phone handset or tablet computer that enables a user to access specific information; make payments and other transactions; send messages; etc. The application (app) is downloaded (for free or for payment) from a wireless network from an online store and may require a live connection to function effectively.

The growth of mobile communication technology is creating a number of opportunities for social empowerment, and grassroots innovation in developing countries. One of the areas with potential impact is in the contribution of mobile applications to Agricultural and Rural Development (ARD), by providing access to information, markets, and services to rural inhabitants (World Bank, 2012). In, India Digital literacy initiated by Digital India (2015) has given fillip and increased availability of bandwidth, cheap data plans and increased awareness driven by government programmes to rapidly bridge the digital gap between urban and rural India.

Emerging Challenges

Even though India's mobile phone users and internet subscribers have outnumbered several developing nations in terms of its usage. Still, farmers in rural areas are yet to reap the benefit of digital revolution and therefore; affordability, accessibility and availability still possess the determining factors for mobile app utility. Mobile applications indeed have a widespread penetration worldwide in all sectors; and to a lesser extent in the agricultural sector. And therefore, the development of mobile apps for agriculture compared with other business sectors is limited. One of the major reasons why the farmers have faced challenges is because they rarely received adequate and timely information on various influencing factors such as weather, rainfall and soil conditions. Similarly, the majority of farmers do not have access to a communications platform that provides market trends and other current updates.

In this era of digital world information farmers face challenges with regard to information management of huge data and the complexity of processes in precision farming. Access to data from the mobile app having different format and different specific contents can be heterogeneous in their structure and format. Thus, creates difficulty for the laymen and farmers to easily access its service. The inventions in technology in agriculture domain

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remains far from reach to the farmers; because of either most of them are illiterates or due to unawareness of the location of information and service provides. Hence, most of the farmers fail to meet the desired production rate thus affecting their rate of production/output. However, research has shown that they have keen interest in learning to operate and use technology which will enable them to take constructive and in time decisions about their farming .Mobile phones do have a multi-dimensional positive impact on sustainable poverty reduction and identify accessibility as the main challenge in harnessing the full potential. Hence, there is an immense opportunity to enhance the broadcasting of agricultural information that farmers receive through the use of ICTs.

Penetration of Smart phones in Agriculture

Among the technologies invented in the past few decades, smartphones have gained large market shares among various user sectors due to their usefulness, ease-of-use, and affordability. A smart phone is the device that is used to make telephone calls, having additional features and abilities like to send and receive e-mail, Wi-Fi and modem ability, internet access, Office documents, easy touch screen operation and most of all the capability to run custom software. The 'user interface' is one more important characteristic of smart phone. The number of smart phone users in India is expected to double to 859 million by 2022 from 468 million users in 2017 growing at a compound annual growth rate (CAGR) of 12.9% (ASSOCHAM-PwC,2019).Mobile subscriptions are expected to reach 1.4 billion by 2021, according to the Ericsson Mobility Report of June 2016. (CNBC, 2016). For India, over the last decade, the markets in both developed and developing countries have been flooded by mobile phones, tablets, and other pervasive devices. Depending on the availability of network 2G and 3G, the applications have helped the farming community at large to be connected, updated, prepared and profitable, (Vodafone, 2010). These mobile-based smart applications potentially deliver timely information to different subscribers such as farmers, traders and producers. The information delivered includes weather, rainfall, crop information at large, while some applications also help update the market data of commodity prices and facilitate the local buying /selling via hand held devices.

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Advantages of Mobile Applications

The advantages of mobile apps include: affordability, wide ownership, voice communication, and instant and convenient service delivery. Due to these, there is explosion across the world in the number of mobile apps, facilitated by the evolution of mobile networks and by the increasing functions and falling prices of mobile handsets (World Bank, 2012). All types of information on crop, soil, climate, rainfall, seeds, and machinery at any point in time, and any number of times is available on finger tips of farmers. For farmers, and their advisers, software tools can facilitate effective farm management by recording data efficiently, analyzing it, and generating a series of evidence-based recommendations. The available information is compiled and very well organized that farmer does not have to waste time while retrieving and referring. The market connectivity is also improved with the visibility and knowledge of the potential buyers and sellers in the locality with an opportunity to develop direct contacts. The commodity prices can be delivered in a real time mode. Mobility can assist the farmers in better warehousing facility by updating their stock, track the dead stock, make note of the purchase requirements and thereby honoring the delivery commitments in a timely manner and getting the stock reach the end consumer and at the same time ensuring quality. Cell phones have a greater impact on price dispersion for participants who are further away from their markets, and for those with worse roads. In addition to it, the farmers can be well updated about their investments, track orders made on purchases, view bank statements, be well informed of insurance details and deadlines and thereby plan the production effectively.

Disadvantages of Mobile Applications

Due to less relative advantage, compatibility, trialability, observability and more complexity of the mobile apps creates difficulty and disadvantageous for its user to easily access the applications. With the diversity in languages, even if the best of the applications do not support regional languages then translation will be required at all stages which will increase the dependency and in turn reduce the acceptability and popularity. At times, due to network issues, speed of the data delivery, legal restrictions, it might prevent the farmers by getting the updated and complete information. There may be a requirement of a skilled person to understand and translate the various complex functions to be performed on farm, ambiguous information and videos in other languages. The farmers in the developing nations

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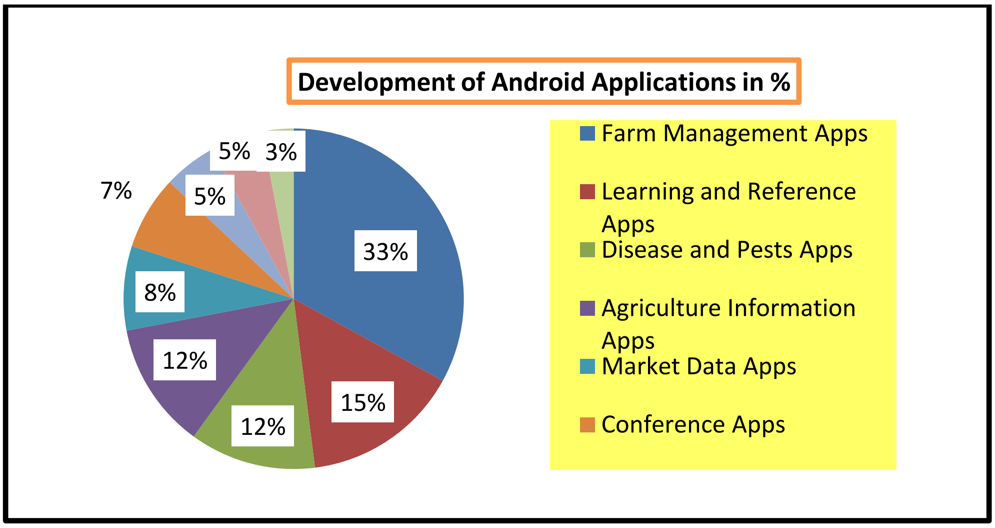
may not be adequately equipped to afford and use the applications which may be chargeable and also require huge data usage thereby levying the network charges on the burdened shoulders of the farmer (World Bank 2011).



Source: Patel, H., & Patel, D. (2016)

Conclusion

Mobile technology is transforming access to information among farming masses. Emergence of digital revolution and internet penetration in the rural areas has enthralled farmers to access to new apps that would keep pace with the modern technology. A number of new apps are emerging in response to new requirements and challenges in agriculture and allied sector. As the number of apps continue to increase it is important to be selective in choosing the app, review and ensure that the App provides credible and current information and meets requirements. Since agricultural work is context-based, which is primarily distinguishable by different geographical locations, smart phone applications already available in one scope of context can be developed to fit other crops or countries or regions. Hence, mobile app should aim at holistic rural development and forge closer links between farmers and consumers through gender-sensitive technology, training and capacity building of the farmers through technology-driven platforms for income generation activities.

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HYDROPONICS : A STEP TOWARD FOOD SECURITY

Article Id: AL202038

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Water, energy and food systems are inter-linked via a nexus. In the basic sense, one joule of energy produced, inputs into one drop of water distributed, which grows one calorie of food. Similarly, a single drop of water inputs into a single joule of energy needed for one calorie of grain grown. Therefore, action on one system impacts the others.

This complexity is compounded by the fact that climatic conditions are deteriorating with time and a significant increase in global population is a major factor. Constant escalation in urbanisation and industrialization will require more water, energy and food resources in the future (Kiani, A.2019).

Althought, India has only about 4 per cent of the world's renewable water resources but is home to nearly 18 per cent of the world's population and to fulfil the demand of food for ever-increasing population where, the availability of arable land is decreasing due to urbanization and deforestation and water for irrigation purpose is decreasing day-by-day, there must be an alternative for tradition farming like hydroponics to overcome such challenges.

Hydroponics is a system of agriculture that utilizes nutrient-laden water rather than soil for plant nourishment (Bridgewood, 2003). Because it does not require natural precipitation or fertile land in order to be effective, it presents people who are living in arid regions with a means to grow food for themselves and for profit. The re-use of nutrient water supplies makes process-induced eutrophication (excessive plant growth due to overabundant nutrients) and general pollution of land and water unlikely, since runoff in weather-independent facilities is not a concern.

Aeroponic and hydroponic systems do not require pesticides, require less water and space than traditional agricultural systems, and may be stacked (if outfitted with led lighting) in order to limit space use (vertical farming) (Growing Power, 2011; Marginson,

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2010). This makes them optimal for use in cities, where space is particularly limited and populations are high-self-sustaining city-based food systems mean a reduced strain on distant farms, the reduction of habitat intrusions, fewer food miles, and fewer carbon emissions.

How does it work?

In conventional agriculture, soil supports a plant's roots – helping it to remain upright – and provides it with the nutrients it needs to grow. In hydroponics, plants are artificially supported, and a solution of ionic compounds provides nutrients instead.

The thinking behind this is simple. Plant growth is often limited by environmental factors. By applying a nutrient solution directly to a plant's roots in a controlled environment, a farmer can ensure that the plant always has an optimal supply of water and nutrients. This nutritional efficiency makes the plant more productive.

The solution can be delivered in a number of ways. A plant may be:

- placed in an inert substance (such as the volcanic glass perlite or rock wool) and have its roots periodically flooded with solution
- placed in an inert substance and rained on by a solution dripper
- suspended with its roots in the air, with these then sprayed with solution mist
- placed on a slightly sloping film that allows solution to trickle over its roots

All of these systems are mechanised in one way or another, usually using either a pump or a mister to deliver the solution from a separate store. The solution is also usually aerated to ensure that the roots are supplied with adequate oxygen. Mineral absorption requires energy, and is powered by respiration.

Higher yield as compared to conventional agriculture practices

According to the FAO, due to the increasing population, food production is expected to rise by 70% before 2050. On the other hand, natural prerequisites of agriculture, *viz.*, arable land and water have been depleting, with rapid urbanization across the globe. To feed the increasing population, the productivity of food crops needs to be increased in the existing arable land, and also alternative farming techniques such as urban farming need to be encouraged.

Hydroponic systems or soil-less agriculture reduce the farmer's consumption of resources, thereby enabling this farming technique to be adopted by a large number of stakeholders, ranging from home gardeners to professional growers, and supermarkets to restaurants. According to the UN reports on global population, plants grown in hydroponic systems have achieved 20%–25% higher yield than the traditional agriculture system, with its productivity being 2–5 times higher. Also, owing to controlled environmental conditions, the effect of climatic changes can be balanced with the help of these systems, thereby not affecting the annual crop production. CEH techniques directly affect the crop harvest cycle; hence, for hydroponic systems, crop harvest cycles are shorter in comparison to traditional farming techniques, thereby increasing the annual yield. Also, since climatic changes show a minimal effect on such systems, crops can be produced all year round, thereby again increasing the produce.

Hydroponic crops

Theoretically, hydroponics can be used to grow any crop. However, the technique is mostly used with plants that grow efficiently under hydroponic conditions, such as salad greens, cucumbers, peppers and herbs. Most commonly it is used to grow tomatoes.

Farmers tend to use hydroponics with tomato varieties that have had special characteristics bred into them, such as bearing larger fruit and growing indeterminately (meaning that they grow continually, repeatedly producing fruit along their stems).Disease-resistant varieties are also popular as they enable plants to live for longer and bear more produce. On the other hand, crops that are not genetically suited to hydroponics are avoided, such as wheat.

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Hydroponic farming has been majorly adopted for vegetable production

The major factor for higher adoption of hydroponic farming in vegetable production is the yield obtained, which can be up to 10 times higher than traditional farming techniques. Since the capital cost involved in hydroponic setup is high, the crops produced are sold at premium rates, and according to industry experts, the price of the produce ranges at par with the organic produce prices. Vegetables that are grown using hydroponics are known to grow faster and stronger compared to traditional farming, as the right nutrients are delivered directly to the plants' roots.

Hydroponics Fodder for cattle rearing

The use of nutrient solution for the growth of the hydroponics fodder is not essential and only the tap water can be used. In India, maize grain should be the choice for production of hydroponics fodder. The hydroponics green fodder looks like a mat of 20-30 cm height consisting of roots, seeds and plants. To produce one kg of fresh hydroponics maize fodder (7-d), about 1.50-3.0 litres of water is required. Yields of 5-6 folds on fresh basis and DM content of 11-14% are common for hydroponics maize fodder, however, DM content up to 18% has also been observed. The hydroponics fodder is more palatable, digestible and nutritious while imparting other health benefits to the animals. The cost of seed contributes about 90% of the total cost of production of hydroponics maize fodder. It is recommended to supplement about 5-10 kg fresh hydroponics maize fodder per cow per day. However, sprouting a part of the maize of the concentrate mixture for hydroponics fodder production does not require extra maize. Feeding of hydroponics fodder increases the digestibility of the nutrients of the ration which could contribute towards increase in milk production (8-13%). In situations, where conventional green fodder cannot be grown successfully, hydroponics fodder can be produced by the farmers for feeding their dairy animals using low cost devices(Naik,2015).

Urban farming

The vast majority of plants are still grown using soil, but hydroponics is on the rise. In 2013, Thanet Earth – the UK's largest greenhouse complex, based in Kent – used controlled-environment agriculture to produce around 225 million tomatoes, 16m peppers and 13m cucumbers, which equated respectively to 12, 11 and 8 per cent of Britain's entire

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annual production of these crops. It currently operates four greenhouses, and has plans to build another three.

Globally, it was estimated that the hydroponic farming industry was worth $21.4 billion in 2015, with its value projected to grow at 7 per cent per year. Slowly but steadily, farming appears to be changing.

But equally, there are big global changes on the horizon, and these could vastly accelerate the use of controlled-environment agriculture. By 2050, an extra 3bn people could be living on Earth, with over 80 per cent of the global population living in urban centres. We're already using the vast majority of land suitable for raising crops, so new growing areas – particularly in arid regions – need to be found.

One much-talked-about solution is vertical urban farming – creating stacked hydroponic farms inside buildings, including tall skyscrapers. This would solve the problem of running out of available farmland, and also place farms right at the heart of where crops are needed – our densely populated cities of the future. Vertical farms are already being built in Michigan and Singapore – and even in disused bomb shelters in south London. And, as it plans human space missions that will travel further and further from Earth, NASA is investigating whether hydroponics could be used to create space farms to feed astronauts. Working with the University of Arizona, it is seeing whether it can create a closed-loop system that feeds human waste and CO_2 into a hydroponic farm to create food, oxygen and water.

Hydroponic systems are essential tools for plant production in indoor farming such as plant factories with artificial lighting (PFALs). Among various hydroponic systems, the deep flow technique (DFT), nutrient film technique (NFT), and aeroponic systems have been commercially used with recirculated nutrient solutions. To protect the plants in plant factories from disease, disinfection systems, such as ultraviolet (UV) systems, are required. The light intensity and exposure time of UV radiation are related to the disinfection ratio of pathogens. The hydroponic systems, sensors and controllers, nutrient management systems, ion-specific nutrient management, and nutrient sterilization systems required for plant production in plant factories.

Success stories in India

Future Farms based in Chennai, India has developed effective and accessible farming kits to facilitate hydroponics. The company develops indigenous systems and solutions, made from premium, food-grade materials that are efficient and affordable for Indian growers.

Junga FreshnGreen, an agri-tech start-up, is a joint venture with a leading Netherlands-based Agricultural technology company – Westlandse Project Combinatie BV (WPC). It is setting up high-technology farms in India. The company will create a hydroponics model that can cultivate farm fresh vegetables that have a predictable quality, having little or no pesticides, and unaffected by weather or soil conditions.

Limitations

1. Lack of government policy and tax breaks in developing countries

Hydroponic farming is seen as a key factor in improving food security in developing regions; however, while government support through tax cuts is present in developed countries, the same cannot be said for developing countries. The availability of the best equipment is fairly limited and often needs to be imported, which attracts taxes adding to the costs for hydroponic growers. The lack of tax cuts and incentives is also a key factor that hinders the growth of hydroponics in developing regions as the high set-up costs and running costs can often render operations unfeasible. The need for basic training and technical knowledge is necessary for operating hydroponic farms, which although is present in developing countries, does not add significantly to the value of hydroponic farms. The high costs of production often result in high costs of the final product, which in itself can draw consumers away in price-sensitive markets.

2. Spread of waterborne diseases and algae in closed systems

In a closed hydroponic system, the threat of waterborne diseases poses a major problem to growers. Considering that the nutrient-enriched water is recirculated throughout the system, any kind of waterborne disease that enters the nutrient reservoir often affects the whole crop as it has the capability to spread throughout. Growers often keep their plants spaced out to prevent crowding, which is often how pathogens enter the system.

The modulation of internal temperatures is also a crucial step as heat and moisture in an irrigation system if left untreated can result in the formation of molds and algae, which can draw nutrients from the water, thereby leaving little for plants, thereby affecting the crops in the process. To combat the instances of waterborne diseases, growers are resorting to using screen or paper filters and additional filtration systems to curb the spread of waterborne diseases in the system. Other safety measures included in systems include a rapid flush system to drain the water from the crops and prevent the spread of any pathogens.

Conclusion

From the above discussion it is evident that in near future when there will be inadequacy of the cultivable land due to urbanization and deforestation for providing the shelter to outbreaking population, there will also be requirement of alternative of traditional farming and in that case, hydroponic may be a step toward food security. Today farmers are slowly increasing their use of hydroponics, and researchers are looking more closely at how it could solve future food problems. In the future, some of its applications could be out of this world. Hydroponics also give wings to the Urban farms and animal husbandry.

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IMPACT OF CLIMATE CHANGE ON AGRICULTURAL SUSTAINABILITY

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Climate change may be defined as periodic modification of Earth's climate brought about as a result of changes in the atmosphere as well as interactions between the atmosphere and various other geologic, chemical, biological, and geographic factors within the Earth system. Climate is often defined loosely as the average weather at a particular place, including parameters such as temperature, precipitation, humidity and windiness.

Climate change has significant impact on agricultural sector in many ways, and these impacts vary from region to region. For example, climate change is expected to increase temperature and precipitation variability, reduce the predictability of seasonal weather patterns and increase the frequency and intensity of severe weather events, such as floods, cyclones and hurricanes. Some regions are expected to face prolonged drought and water shortages.

The increasing population has resulted in increased demand for food. This results in pressure on natural resources. *By 2020, pressure on India's water, air, soil, and forests is expected to become the highest in the world (World Bank).* Climate change is expected to negatively affect both crop and livestock production systems in most regions. The changing climate is also adding to resource problems, such as water scarcity, pollution and soil degradation. Climate change will affect agricultural yield directly because of alterations in temperature and rainfall, and indirectly through changes in soil quality, pests, and diseases. The yield of cereals is expected to decline in India. Extreme weather conditions such as high temperature, heavy rainfall, floods, droughts, etc. will also affect crop production.

Climate changes related to the greenhouse gas emissions (GHG) are seen as one of the major threats to sustainable human development. Agriculture contributes a significant share of the greenhouse gas (GHG) emissions that are causing climate change 17% directly through agricultural activities and an additional 7-14% through changes in land use. It is therefore both part of the problem – and potentially an important part of the solution. (OECD, Meeting of Agriculture Ministers, April 2016). The main direct agricultural GHG emissions are nitrous oxide emissions from soils, fertilisers, manure and urine from grazing animals; and methane production by ruminant animals and from paddy rice cultivation. Both of these gases have a significantly higher global warming potential than carbon dioxide.

Climate change has created challenges for the agricultural sector – and will continue to do so. One cannot deny the relation of agriculture and climate change. The negative effect of climatic change makes farm and farm community more vulnerable to face its repercussions. The agriculture being climate based enterprise has to deal with the extreme climatic events which are unprecedented and less predictable. Climate change induced increases in temperatures, rainfall variation and the frequency and intensity of extreme weather events are adding to pressures on global agricultural and food systems.

Climate Smart or Climate Resilient Agriculture

Self-initiated efforts by farmers to adapt to climate change while decreasing the GHG footprint of agriculture are unlikely to be sufficient, given uncertainties surrounding the timing and nature of climate change. The action must be undertaken, which would have to reduce the GHG emissions from agriculture and/or adaptation of agricultural production to the new conditions, so that the productivity of the sector, i.e. agriculture, is not diminished. The Climate-Smart Agriculture is a viable alternative. This term should be understood as targeting the agricultural practices to reduce its negative impact on the environment, and consequently also on the climate. Two strategies are used in the process of climate-friendly agriculture management, noting that agricultural practices can mitigate the climate changes (reduction of GHG emissions), or adapting agriculture to the already noticeable changes (development of soil and water quality, sustainable agronomy, animal breeding, or crop rotation).

The Food and Agricultural Organisation (FAO) defines Climate-Smart Agriculture (CSA) as an approach that helps guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. It takes into consideration the diversity of social, economic and environmental contexts, including agro-ecological zones. Implementation requires identification of climate-resilient technologies and practices for management of water, energy, land, crops, livestock, etc at the farm level. It also considers the links between agricultural production and livelihoods. Testing and applying different practices are important to expand the evidence base and determine what is suitable in each context.

Initiatives taken towards sustainable agriculture in country

1. **The National Water Policy (2002)** stresses that non-conventional methods for utilization of water, including inter-basin transfers, artificial recharge of groundwater, and desalination of brackish or sea water, as well as traditional water conservation practices like rainwater harvesting, including roof-top rainwater harvesting, should be practiced to increase the utilizable water resources. Many states now have mandatory water harvesting programmes in several cities.

2. **National Mission for Sustainable Agriculture** is one the eight missions in the National Action Plan on Climate Change (NAPCC) aims to support climate adaptation in agriculture through the development of climate-resilient crops, expansion of weather insurance mechanisms and agricultural practices. The mission focuses on four areas that are relevant for the endeavours of India's agricultural sector to adapt to climate change:

- Dry land agriculture
- Risk management
- Access to information
- Use of technology

3. National Innovations on Climate Resilient Agriculture (NICRA) was launched during February 2011 by Indian Council of Agricultural Research (ICAR) with the funding from Ministry of Agriculture, Government of India. The mega project has three major objectives of strategic research, technology demonstrations and capacity building.

Assessment of the impact of climate change simultaneous with formulation of adaptive strategies is the prime approach under strategic research across all sectors of agriculture, dairying and fisheries. Evolving climate resilient agricultural technologies that would increase farm production and productivity vis-à-vis continuous management of natural and manmade resources constitute an integral part of sustaining agriculture in the era of climate change. The four modules of NICRA – natural resource management, improving soil health, crop production and livestock – is aimed making the farmers self-reliant

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4. **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)** envisages "Per Drop More Crop", that is, promoting micro/drip irrigation to conserve water. The scheme will be implemented by Ministries of Agriculture, Water Resources and Rural Development. Ministry of Rural Development is to mainly undertake rain water conservation, construction of farm pond, water harvesting structures, small check dams and contour bunding etc. MoWR, RD &GR, is to undertake various measures for creation of assured irrigation source, construction of diversion canals, field channels, water diversion/ lift irrigation, including development of water distribution systems.

5. **Paramparagat Krishi Vikas Yojana (PKVY)** an initiative to promote organic farming in the country through cluster-based approach. Fifty or more farmers form a cluster having 50 acre land to take organic farming. Each farmer will be provided Rs. 20000 per acre in three years for seed to harvesting crops and to transport them to market.

Conclusion

It is clear that the occurrence of floods and droughts, heat and cold waves are common across the world due to climate change. Their adverse impact on livelihood of farmers is tremendous. It is more so in India as our economy is more dependent on agriculture. Interestingly, weather extremes of opposite in nature like cold and heat waves and floods and droughts are noticed within the same year over the same region or in different regions and likely to increase in ensuing decades. The human and crop losses are likely to be heavy. The whole climate change is associated with increasing greenhouse gases and human induced aerosols and the imbalance between them may lead to uncertainty even in year-to-year monsoon behavior over India.

Therefore, there should be a determined effort from developed and developing countries to make industrialization environment friendly by reducing greenhouse gases pumping into the atmosphere. In the same fashion, awareness programmes on climate change and its effects on various sectors viz., agriculture, health, infrastructure, water, forestry, fisheries, land and ocean biodiversity and sea level and the role played by human interventions in climate change need to be taken up on priority basis.

In the process, lifestyles of people should also be changed so as not to harm earth atmosphere continuum by pumping greenhouse gases and CFCs into the atmosphere. Also, there is need to guide farmers on projected impact climate change and sensitise them on probable mitigation and adaptation options to minimize the risk in agricultural sector.

Way Forward

Policy reforms as suggested by OECD, Meeting of Agriculture Ministers, April 2016.

1. Wider social, economic and environmental policy settings – such as trade, investment, infrastructure, and education policies – should consistently support sustainable productivity growth, in combination with adaptation and mitigation efforts.
2. There is a need to reform misaligned and distortive agricultural policies that encourage unsustainable intensification and the overuse of natural resources and potentially damaging inputs.
3. Policies that aim to address climate change should emphasize outcome-based farmer incentives and knowledge transfer systems.
4. Governments should ensure the provision and dissemination of relevant and up-to-date information on resource use efficiency and risk management.

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AN OVERVIEW OF FARMER FIRST PROGRAMME OF NDRI, KARNAL

Article Id: AL202040

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The Indian agriculture and dairying has witnessed a quantum jump in production through various extension approaches by the Government of India and Indian Council of Agricultural Research (ICAR). These approaches brought lot of success in terms of raising production & productivity and addressing issues of the farmers but in these approaches technology was considered as an important factor than the farmers, farmer was considered as a recipient of the technology outputs. Due to changed agricultural situation there is a need of new approaches for project development involving innovation and technology development involving innovation and technology development with the strong partnership of the farmers for developing location specific , demand driven and farmer friendly technological options. So ICAR comes with new programme called the farmer FIRST (Farm, Innovations, Resources, Science Technology) in October,2016.

Farmer FIRST Programme of NDRI, Karnal

Under the farmer FIRST programme of ICAR, National Dairy Research Institute, Karnal undertaken the project entitled "Capacity Building of Resource Poor Farmers in Paddy-Wheat cum Dairy Production System through Farmer FIRST Programme under Irrigated Agro-Eco Region of Haryana**".** This project was implemented in the following villages of Karnaldistrict namely Samora, Churni, KamalpurRoarn, NaglaRoarn and Garhigujaran.

Technological interventions under the Project

Initial interaction and discussion with farmers helps in identifying their needs, problems and accordingly the following interventions were implemented under this project from 2016-18.

SI NO	Category	Interventions	No. of Households covered
1	**Crop based Interventions**	Integrated Pest Management (IPM) in Paddy	150
2		Effective weed control measures in wheat in Wheat for Higher productivity and income under paddy- wheat production system	100
3		Integrated Nutrient Management in Wheat	148
4		Introduction of Dhaincha crop in summer to improve soil health & for fodder availability	25
5		Round the year Green fodder production (Napier grass with seasonal fodder crops)	183
6	**Dairy based Interventions**	Balanced feeding technology for higher milk production in dairy cows/buffaloes	58
7		Minerals and Vitamin supplementation in cows and buffaloes	392
8		Bypass fat supplementation	57
9		Mastitis control programme using CMT & AST as effective diagnostic procedures	143
10		Control of Ecto& Endo-parasitic infestation among dairy animals	117
11		Theliariosis control programme in cross-breed cows	220
12		Estrus Synchronization in dairy animals	114
13		Ovulation Synchronization in dairy animals	132
14	**Advisory based**	Development of SMS portal for the farmers	Full coverage
15	**Horticultural based**	Vegetable based cropping systems	67
16		Introduction of fruit cultivation as nutritional gardens	82
17	**Enterprise based**	Milk processing unit for self-employment	1 unit

(Source: Annual report (2018) on farmer FIRST programme of NDRI)

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Results of the technological interventions

SI NO	Category	Interventions	Results
1	**Crop based Interventions**	Integrated Pest Management (IPM) in Paddy	Healthier crop yield upto 23-24 q/acre at farmers field
2		Effective weed control measures in wheat in Wheat for Higher productivity and income under paddy-wheat production system	Weed free crop with average yield of 24-26 q/acre at farmers field
3		Integrated Nutrient Management in Wheat	Use of all possible sources on nutrient management resulted in higher productivity
4		Introduction of Dhaincha crop in summer to improve soil health & for fodder availability	Dhaincha crop provided leguminous fodder @160q/ha. incorporation of dhaincha into soil has reduced the pH& EC and increased organic carbon
5		Round the year Green fodder production (Napier grass with seasonal fodder crops)	Increased green fodder supply throughout the year & increased area under fodder crops
6	**Dairy based Interventions**	Balanced feeding technology for higher milk production in dairy cows/buffaloes	Along with increase in milk yield Fat & SNF content in the milk has also been increased
7		Minerals and Vitamin supplementation in cows and buffaloes	Increase in milk yield & reproductive parameters of the animals were also favorably improved
8		Bypass fat supplementation	Average increase in milk yield 1-1.5 litres. Improvement in body condition score. Increase in fat & SNF was noticed
9		Mastitis control programme using CMT & AST as effective diagnostic procedures	Farmers awareness regarding control of mastitis was observed
10		Control of Ecto& Endo-parasitic infestation among dairy animals	Reduced infestation of ecto/endo parasites and also increase in milk yield & animal performance was observed
11		Theliariosis control programme in cross-breed cows	The vaccinated animals were observed fully protective.
12		Estrus Synchronization in dairy animals	Overall success rate was observed as 76% and proved to be set tool to tackle the existing infertility problems in dairy animals
13		Ovulation Synchronization in dairy animals	Observed success rate was 78%
14	**Advisory based**	Development of SMS portal for the farmers	Helping in organizing & disseminating technological and other related information
15	**Horticultural based**	Vegetable based cropping systems	Additional income from vegetable cultivation
16		Introduction of fruit cultivation as nutritional gardens	Good growth of plants
17	**Enterprise based**	Milk processing unit for self-employment	Group of 15 persons were given training at NDRI. One entrepreneur is successfully running dairy unit in the Samora village as VIREN DAIRY.

(Source: Annual report (2018) on farmer FIRST programme of NDRI)

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Apart from these study conducted by Begum, M (2018) on Assessment of Interventions implemented under Farmer FIRST Programme of NDRI show the following results

- Theoverall extent of knowledge inEcto-parasite control was 86.25 percent followed by cultivation of Maize round the fodder production (86.00 %).
- The percent of knowledge gain was highest in case of Mineral mixture about 85.00 percent followed by Theilariosis vaccine about 83.50 percent.
- The benefit/cost ratio was calculated 1.63:1 in case of DSR, IPM in paddy was 2.12:1 and for fodder maize was 1.63:1.
- The economic performance of dairy intervention was observed in terms of increase in milk yield, improvement in health and reduced risk of disease occurrence.
- The major feedback about the crop implemented interventionswere very poor germination percentage in DSR technology, reduced risk of pest attack due to use of IPM in paddy and Dhaincha improved the soil health.

Activities under this project

FFP project teamField Visits

Training to farmers

Treatment to animals

(Source: NDRI FFP web portal)

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Conclusion

The programme is running successfully with good responses from the farmers. Farmers were benefited from the different interventions under this programme. The major feedback about the crop implemented intervention was reduced risk of pest attack due to IPM and Dhaincha improved the soil heath. The major feedback about the dairy implemented intervention was increase in milk yield, increase in reproductive efficiency and improvement in health.The economic performance of most of the selected interventions helped to increase the income of respondents

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PEARL MILLET - POTENTIAL TO BOOSTS RAINFED FARMERS LIVELIHOODS AND NUTRITIONAL SECURITY

Article Id: AL202041

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In India, nearly 60 per cent net sown area is under rain-fed farming, which is completely dependent on monsoon rains. About 55 per cent of India's farmers rely on agriculture as a source of food, income and employment. Over the years, farmers in rain-fed areas have been facing several adversities such as climate variability, crop failure, non-remunerative prices, etc. Their adverse impact on livelihood of farmers is remarkable, as India's economy is more dependent on agriculture. To make agriculture a viable and adaptable proposition in the country, there is a need to do more research and development in rain-fed agriculture. Presently, climate change and hidden hunger are the major bottlenecks that hamper the productivity, healthiness and economic potential of people living on the margins. Crop and dietary diversification of the rain-fed region is limiting due to seasonality and socio economic status. Under this perspective, rain-fed agriculture is risk prone activity and creating panic situation in the backdrop of observed erratic weather and threatening food production and rural livelihoods. In this sense, it is very crucial to elect right crops, which have the ability to buffer crop production against these multiple stresses linked with climate change and produce sustainable yield with minimum inputs to grab the maximum profitability.

Certainly, millet crops are a critical solution to climate change and ideal option for rain-fed farming systems. Traditionally, under drought threat scenario, millets provide nutritious food as compared to other cereals with high fibre content and essential minerals. By default, millets can be grown organically and may not require chemical fertilizers and pesticides. Indeed, "Millets - Climate Smart Crops" are the hope for food-cum-nutritional security, where not only enough calories but also necessary micronutrients are taken care. More recently, successful biofortification of millets to combat chief hurdles of dry region, a major breakthrough to beat the malnutrition and rural poverty and be more sustainable on the environment. To revive millets to mainstream, exploit their nutritional and nutraceuticals properties, Govt. of India declared the year 2018 as "National Year of Millets". Further, acting on India's proposal, the Food and Agriculture Organization (FAO) of the United Nations has agreed to celebrate "International Year of Millets" in 2023 with theme ofimproving production and productivity of the climate-resilient and nutritious millets across the globe. Furthermore, to ensure, it reaches the masses, it has been brought into the PDS (Public Distribution System) to encourage consumption of millets for balanced diet in the changed dietary patron of the modern society. There is no doubt that a rapid shift in the cropping pattern and eating habits incorporating millets in today's population is vital.

Promise of Pearl Millet

Technically, among the millets pearl millet is the most sustainable crop in the rain-fed conditions due to its unique traits – C_4 short duration plant with high photosynthetic efficiency, inherent high water-use efficiency and can withstand in most adverse agro-climatic conditions. It can give farmers a harvest even under water deficit/salinity/heat stress where there is none for other crops, reducing farmers' risk of losses. It is the one of the toughest, drought-tolerant crops due to its rapid and extended root system with specialized cell walls that prevents desiccation.

Pearl millet is the cheapest source of minerals as compared to other cereals and vegetables. It is an extremely versatile ingredient of nutrients, which are vital for humans' growth and rightly termed as "nutricereal" along with other millets. Its protein quality is superior in term of its tryptophan and lysine along with higher content of calcium,potassium, magnesium, iron, zinc as well as niacin, riboflavin, thiamine. With low prolamine fraction, pearl millet is gluten free grain and the only grain retains its alkaline properties after being cooked, which is ideal for people with gluten allergy. Pearl millet is rich in fibre content, it tends to digest slowly and release glucose at a slower rate and curbs hunger for a long span of time, as such it is powerful in controlling diabetes and aids in weight loss. It contains "phytic acid" which is believed to stabilize the level of cholesterol in the body. Regular intake of pearl millet protects from developing breast cancer and reduces secretion of bile acids and is linked to a lowered risk of gallstone formation. Pearl millet is traditionally used for food products like roti (flat bread), bhakri (stiff roti) and porridge. Unlike other millets, pearl millet required little processing for new products. Pearl millet flour mixed with wheat flour for making baking products like breads, cakes, muffins, cookies, biscuits and non-alcoholic beverages.

Pearl millet forage has higher levels of protein content than sorghum and maize and found to be a crop of choice for animal and poultry feed, particularly in dryland areas. Pearl millet responds profitably to a balanced application of plant nutrients. In spite of the facts, the area under pearl millet cultivation has been drastically reduced over the years in India. Wherever, there are no alternatives the resource poor rain-fed farmers continue to grow in foreseeable futures to meet out the needs of food and their animal feed and fodder. Currently, in India it is mostly grown in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh Haryana and small fraction in other states,where weather variability and poor soil fertility with low water-holding capacity are common characters of the area. Accounting an area of 7.5 million hectare and contributing 9.73 million tonnes of grain in India. Interestingly, pearl millet productivity has increased noticeably over time, in 1981 it was 458 kg ha^{-1} which reached 1305 kg ha^{-1} in 2018.

Impact of climate change on pearl millet

With alarming concern of climate change, rise in temperature, changes in precipitation patterns and elevated CO_2 concentration are the major predicted impacts, which have significant implications on agricultural productivity. In most of the cases, pearl millet is remained answer to the erratic weather, because it offers the potential to reduce agricultural water demand and also alleviate certain micronutrients deficiencies. Peal millet can thrive well at optimum temperatures of 33°C day and 28°C night. Eventhough, the crop can tolerate temperatures of up to 42°C, whereas other cereals, like maize (40°C) and rice (32°C) and wheat (30°C) cannot handle the heat. Currently, several high yielding and heat-tolerant hybrids are available having good seed set at air temperatures as high as 46°C and finding a new niche in north-western India as a irrigated crop. Another implication of climate change is elevated Carbon dioxide (CO_2) concentration, it is expected to have positive physiological effects through increased photosynthesis and in-turn beneficial effect on crop growth and yield. The benefit of “CO_2 fertilization” effect on yield may partially minimized the negative impacts of rising temperature. However, scientific results shows carbon penalty from increasing CO_2 concentration on protein, iron and zinc more than negates any benefits of CO_2 yield fertilization. On other hand countering the effects of rising CO_2 levels, biofortification of staple crops are likely to take on new importance.

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Biofortification of Pearl Millet

Besides building climate resilience, pearl millet can effectively address the malnutrition of resource poor and life style disease of urban people. Furthermore strengthening to this, All India Coordinated Research Project on Pearl Millet prioritized nutrition in breeding by officially setting minimum standard levels of iron (42 ppm) and zinc (32 ppm), apart from giving a higher yield for the central release of pearl millet cultivars. Thus, biofortification of pearl millet through conventional breeding opens up the possibility of a cost-effective strategy to beat hidden hunger in women and children while simultaneously providing smallholder farmers a climate-ready crop to face the vagaries of climate change. The high yielding biofortified cultivars assume great significance for nutritional security. The details of recently developed and released ones through AICRP network are presented below.

S. No	**Name of hybrid/variety**	**Bred at**	**Area of adaptation**	**Salient features**	**Grain yield (kg/h)**	**Fodder yield (q/h)**	**Fe (ppm)**	**Zn (ppm)**
Varieties								
1	**Dhanshakti**	Mahatma Phule Krishi Vidyapeeth, Dhule, Maharashtra	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, Haryana Gujarat, Punjab and Uttara Pradesh	Early maturing variety, bold, globular, shining slate grey coloured seed, cylindrical-Lanceolate Earhead, resistant to downy mildew	2199	53	81	43
2	Central Pearl Millet Variety **ABV 04** (MP552)	ARS, ANGRAU, Ananthapuramu, Andhra Pradesh	Maharashtra, Karnataka, Andhra Pradesh, Telangana and	Medium maturing tall and erect plant type; Resistant to downy	2500	58	70	63

			Tamil Nadu.	mildew, smut and blast diseases; tolerant to drought; Panicles are thick and compact with grey coloured obovate shaped bold sized seed				
Hybrids								
3	**HHB 299**	ChaudharyCharan Singh-Haryana Agricultural University, Hisar	Haryana, Rajasthan, Gujarat, Punjab, Delhi, Maharashtra and Tamil Nadu.	Medium maturing, purple anther colour, Lanceolate shaped compact panicle, greyish hexagonal shape grains, resistant to major diseases and insect pests.	3274	73	73	41
4	**AHB 1200** (AHB1200Fe) (MH 2072)	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbani, Maharashtra	Rajasthan, Gujarat, Haryana, Punjab, Delhi, Maharashtra, Telangana, Andhra Pradesh and Tamil Nadu.	Medium maturing, high Fe content, long cylindrical panicle, resistant to downy mildew, resistant to stem borer, highly responsive to fertilizers.	3170	70	77	39

5	**AHB 1269** (AHB1269Fe) (MH 2185)	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbani, Maharashtra	Rajasthan, Gujarat, Haryana, Punjab, Delhi, Maharashtra, Telangana, Andhra Pradesh and Tamil Nadu.	Medium maturing,Non-lodging, high Fe content, cylindrical panicle, resistant to downy mildew.	3200	60	91	45
6	**PhuleMahashakti** (DHBH 1211/MH 2078)	Mahatma Phule Krishi Vidyapeeth, Dhule, Maharashtra	Maharashtra	Very compact earhead, bold globular grains with gray colour.Resistant to downy mildew	2900	60	87	43

To accelerate progress towards ending hunger and safeguard food security and improved nutrition, there is a dire need to promote nutrition sensitive agriculture, where in cultivation of biofortified varieties require no more water and fertilizers than the regular varieties. Consumption of biofortified pearl millet can minimize the deleterious effects of nutrient deficiencies by providing significant amount of the iron and zinc needed daily by young children and women, further resulting in profound positive impacts on livelihoods.

Performance of ABV 04

Ananthapuramu is the drought prone district of Andhra Pradesh and it is located in Scarce Rainfall Zone of the state with normal rainfall of 546.0 mm. NGOs like MYRADA have taken pearl millet to small and marginal farmers in rain-fed areas of Ananthapuramu with a vision of reintroducing millet-based multi-cropping system. With their enthusiasm a farmer A. Sreeramulu, cultivated pearl millet variety ABV 04 during *kharif* 2018, which gave encouraging results of reaping 10 quintals of grain yield per acre using just one bag of urea and no other chemicals inputs. As such, a drought tolerant variety ABV 04 has witnessed

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bumper yield under 47 per cent of deficient rainfall observed during the crop season, where dismal yield of different crops were noticed.

Conclusions and Way forward

In the face of leading water scarcity, pearl millet is most preferred crop due to its adaptive climate-resilience and nutritional features that can really help the policymakers and farmers to combat drought threat situation. Promotional efforts for millets have made huge demand and significant differences in production. The productivity may be further enhanced by adoption of improved production technologies and may increase economic returns from pearl millet-based crop-livestock production systems. In an overview, pearl millet "a power house of nutrients" is easily accessible and affordable to everyone to address the issues of food security, malnutrition and climate change, while protecting the livelihoods of farmers.

[Performance of biofortified Pearl Millet variety ABV 04 during *Khari* 2018 at Kadiri mandal of Ananthapuramu, Andhra Pradesh.]

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