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Climate-resilient vegetables

for prosperity and sustainability

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Vegetables are universally promoted for ensuring healthy food with critical nutrients (dietary fibre, vitamins, minerals, high amount of antioxidants, and for a balanced diet. Vegetable cultivation is greatly affected by drought, high temperature, floods and unseasonal rainfall as well as use of chemicals. Due to climate change, expanding range of known pests, and diseases, and the emergence of new pests and pathogens in areas previously unknown are the significant hurdles to production. India is the major producer of major vegetables and several important minor vegetables. Besides common green leafy vegetables (spinach beat, amaranth, fenugreek and coriander), there are large number of unexplored leafy vegetables like Indian spinach, chenopodium, water spinach and lotus which are available seasonally. Similarly, many tree vegetables like drumstick, jack fruit and lassora besides bush plant like curry leaf are well suited to rainfed environment.

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VEGETABLES are a low-cost source of nutrition, prevent obesity, diabetes, high cholesterol and heart disease. Edible vegetables come in a wide variety of shape and sizes. Rainfed areas account for nearly 52% of the agricultural land in India. Several unexplored/underutilized vegetables (Indian spinach, chenopodium, water spinach, lotus, faba bean, cluster bean, Indian bean, lima bean, vegetable soybean, winged bean, velvet bean, clove bean, jack bean, sward bean, tree bean, welsh onion, ash gourd, teasel gourd, sweet gourd, ivy gourd, snake gourd, mateera, pointed gourd etc.) have the potential role in improving food security, increase sustainability through reduction in inputs, increase in food quality; a way to preserve and celebrate cultural and dietary diversity, a way to use marginal and wastelands for production. Similarly, several exotic and high value vegetables (chive, leek, broccoli, Brussels sprouts, Chinese cabbage, celery, lettuce, globe artichoke, sweet corn, baby corn, asparagus etc.) are well adapted in our edaphic and climatic conditions; and need to be harnessed for domestic and export purposes. Technologies through systematic research and their adoption by farmers in addition to developmental policies of the government resulted in a tremendous increase in area (11.35 million ha), production (204.83 million tonnes) and productivity (18.0 t/ha). India accounts for 14% of the global acreage and 12% of the production, though vegetables occupied less than 3% of the total cropped area in the country. Vegetable market size has reached 7 lakh crores and is contributing 2.5% to national GDP. State-wise vegetable area as percentage of gross cropped area is highest in West Bengal (14%), followed by Uttar Pradesh (12%) and Madhya Pradesh (9%). The projected demand by 2030 will be 228.60 million tonnes for the increasing population which is 1.5% annually. The total organic produce exported

Table 1. Crop-wise area, production and productivity

Crop	Area ('000 ha)	Production ('000 MT)	Productivity (MT/ha)
Tomato	845.00	21181.00	25.07
Brinjal	749.00	12874.00	17.19
Okra	531.00	6466.00	12.18
Pea	367.00	5846.00	10.31
Cauliflower	473.00	9225.00	19.50
Cabbage	412.00	9560.00	23.20
Tapioca	183.00	6941.00	37.93
Radish	207.00	3263.00	15.76
Beans	261.00	2595.00	9.94
Sweet potato	106.00	1121.00	10.58
Bottle gourd	193.00	3171.00	16.43
Bitter gourd	109.00	1330.00	12.20
Chilli (green)	411.00	4363.00	10.62
Carrot	108.00	1885.00	17.45
Cucumber	117.00	1652.00	14.12
Pumpkin	106.00	2205.00	20.80
Capsicum	37.00	563.00	15.22
Pointed gourd	62.00	725.00	11.69
Potato	2203.00	56173.00	25.50
Onion	1624.00	26641.00	16.40
Other vegetables	1555.00	22665.00	14.58
All India	10859.00	200445.00	18.46

during 2020-21 was 8.88 lakh MT worth ₹7,07,849.52 lakhs.

Strategies for sustainable vegetable production

Promoting export

During 2021-22, India exported fresh vegetables worth ₹5745.54 crores / 767.01 USD Millions; processed vegetables (₹3986.45 crores/ 534.98 USD Millions), and processed cucumber and gherkins (₹1487.30 crores/ 199.46 USD Millions).

Application of smart farming in vegetables

IoT devices like e-Crop helps to do precision farming. Inclusion of auto fertigation, drone based input application and determination of insect pest, diseases, crop canopy, etc. adds to precise and timely interventions which are essential for healthy crop. Artificial Intelligence (AI) has capability to make accurate forecasting on demand, supply and prices. Information and Communication Technology (ICT) and Internet of Things (IoT) are helpful in efficient sorting and grading of the products.

Inclusion of high yielding varieties/hybrids

Through AICRP (Vegetable Crops), a total of 553 vegetable varieties (329 open pollinated, 168 hybrids and 56 open pollinated/hybrids/resistant to different biotic and abiotic stresses) till date are recommended for cultivation in various agro-climatic zones of the country and being adopted by the growers, widely. For example,

'Kashi Pragati' variety of okra, 'Kashi Kanchan' of cowpea and 'Kashi Anmol' of chilli are most successful varieties adopted by farmers in eastern Uttar Pradesh with a record 20% increase in productivity. 'Kashi Kanchan' variety of cowpea has spread all through the length and width of country. High yielding varieties of garden pea (Kashi Nandani, Kashi Uday, Kashi Mukti), pumpkin (Kashi Harit and Kashi Basant), brinjal (Kashi Sandesh) and sponge gourd (Kashi Divya) show an average increase of more than 10% yield at farmers' fields.

Use of quality planting materials

Quality seeds/nursery plants are an essential entry point for sustainability and an approach to increase productivity. For development of seed sector, ICAR institutes, CAUs, SAUs an other government organizations directly joined the hands with the private seed sector, as WorldVeg Breeding Programme is being run with the Asia-Pacific Seed Association and the Africa Seed Trade Association in Asia and Africa, which is noteworthy.

Use of grafting technologies

Use of grafting technologies (elite scion cultivars onto vigorous rootstock cultivars) in climate-resilient vegetable cultivation is rewarding with respect to increase in yield as well as quality, long duration fruiting etc. and addressing 30-40% biotic (resistance to nematode, *Fusarium* and bacterial wilt, etc.) and nearly 60-70% abiotic (salinity, drought, suboptimal temperatures, water availability etc.) problems. For

example, grafted brinjal is covering large areas in our country.

Protected cultivation

The demand in world markets has led to more vegetable production under protected structures (shade net house, modified insect-proof net house, naturally ventilated greenhouses, plastic low tunnels, temporary plastic walls and plastic mulches). In India, ~ 150,000 ha is under protected cultivation. The yield increased up to 4-5 times in capsicum, cucumber, cherry and tomato. The strong wind velocity with sand-storms and continuous high temperature range for the prolonged period (March October) are two prime limiting factors in arid climate. Movable and folding type structure (modifications in low-tunnel to tent type) with polythene as covering material is suitable for early cucurbits sowing under protection and to save the crop from low temperature/frost conditions during the peak winters followed by polythene removal in last week of January. Under extreme cold region, specific polyethylene cladding material in polyhouses and tranches has increased yield and quality of vegetables.

Adoption of Good agricultural practices (GAPs)

The growers must minimize the sources of contaminants (water, manure, soil, insects, rodents, equipment cross-contamination, chemical, pesticides, glass, plastic etc.) and must use clean soil, water, hands, surface etc. in vegetables. 'IndiaGap' envisages a focused approach for GAP, traceability etc. through appropriate infrastructure, record and monitoring along with Agri. Export Zone. Enabling vegetable growers to adopt precise crop management techniques, timely tillage, reduced secondary tillage/no till, ridge tillage, cover crops in the rotation, crop residue mulch on the soil surface etc. will increase sustainable productivity, safety, quality, and economic returns besides reduction in greenhouse gas emissions, waste, and soil and water pollution. Organic protocols are favourable to the environment and restricts the use of hazardous synthetic inputs. Green manuring with legumes with a 2-months summer cultivation of cowpea or a 4-months autumn-winter cultivation of faba bean, contribute significant quantities of atmospheric N_2, to the next tomato crop, which amounted to 120 and 150 Kg/ha, respectively. Organic waste recycling and other nutrient management strategies can meet up to 100%, 60% and 30% of N, P and K requirements, respectively. In hilly areas, tuber bearing legume sohphlang (*Flemingia vestita*) can fix nitrogen up to 250 Kg/ha. Crop demands for nutrients are not constant during the growth, therefore fertilizers can be synchronized by fine tuning its application to the needs. In this regard, site-specific nutrient management can potentially increase the yields in several crops indicating the large realizable potential under rainfed conditions. Field should be cross-ploughed 2-3 times followed by planking. Generally, 50-60 cm wide and 20-25 deep furrows (channels) are made at 1.5-2.5 m distance depending upon crop, cultivar and season for cucurbitaceous vegetables. For solanaceous vegetables, 50-60 cm wide channels are sufficient. With a trellis system of cucurbits and beans, distance between channels should be 2.0 m. In green houses, nitrogen must be appropriately addressed, as the cultivation is longer than open field. Bio-fertilizers (*Rhizobium*, *Azotobacter*, phosphorus solubilizing bacteria), *Jeevaamrit* and *Panchagavya* (catalyses soil microbes and earthworms) are boon for organic production as demand is speeding (25-30%) annually. *Bijamrita* is used as treatment of seed/seedling/planting materials, which also help to produce IAA and GA_3. In hilly region, application of 10 t/ha FYM, 4 t/ha vermicompost, 50% recommended dose of fertilizers + 50% FYM + bio-fertilizers, and 50% RDF + 50% vermicompost + bio-fertilizer resulted in total quality fruit yield. Application of poultry manure @ 7.5 t/ha or 20-30 t/ha FYM or 7.5-10.0 t/ha vermicompost can ensure 28-35% higher yield compared to conventional system. FYM @ 10 t/ha + vermicompost @ 3.5 t/ha or FYM

@ 10 t/ha + poultry manure @ 2.5 t/ha along with the *Azotobacter* and PSB yield comparable to conventional inorganic system in tomato, cabbage, pea, cowpea and okra.

Suitable cropping system

Under vegetable based cropping system with assured irrigation, capsicum-French bean-pea; tomato-okra-broccoli; tomato-okra-cabbage; tomato-okra-toria and tomato-okra-pea has been found economical with 300% cropping intensity. This vegetable based cropping system has income potential of ₹ 63-87/sq. m.

Water harvesting and use of modern irrigation system

The rain water harvesting, *in situ* moisture conservation, reduction in seepage losses by use of lining materials, improvement in conveyance efficiency of irrigation channels, scheduling of irrigation (root zone), change in crop establishment and management practices by crop geometry, adjusting crop growth period and multiple use of irrigation water etc. increases the water-use efficiency. The channel system of irrigation (water saving 30-50%) in sandy soils is most practicable for cucurbits, brinjal, tomato, chilli and beans, which reduces manure and fertilizers (30-35%) and labour cost (25-30%). Morever, it is highly suitable for climate-resilient tuber crops like sweet potato, colocasia, tapioca etc. In arid climate, a short-spell of moisture deficit (3-7 days) affects the plant growth, flowering, fruit set, marketable quality and yield. Therefore, controlled techniques like bubbler or hose-pipe up to crop–field for channel or deep furrow and pressurized (drip and sprinkler, increase yield of 15-50%) must be used as they save 30-40% water and maintains crop rhizosphere almost at field capacity so that the plants do not experience moisture stress. The single lateral line (14-16 mm) at 2.0 m distance with in-line drippers (14 Lph) at 50 cm distance is most appropriate for *kachari*, snap melon, round melon, long melon, mateera, muskmelon, bottle gourd, sponge gourd and ridge gourd. Similarly, with a trellis system of crop cultivation, the laterals at 2.0 m and drippers at 50 cm distance is useful for Indian bean, sword bean, ivy gourd, and bitter gourd. Drip technology also give excellent results in brinjal, tomato, cowpea and cabbage (laterals at 1.0 m apart and drippers at 50 cm). Use of solar energy for running drip and sprinkler will be beneficial. Straw mulch before sowing the seeds or sowing of crops to cover land spaces, conserve the moisture and limits the weeds. In hilly area, highest marketable head yield (22.75 t/ha) in broccoli with hybrid 'Pushpa' using dry weed biomass mulch of *Eupatorium* and *Ambrosia* spp. @ 1 kg/m^2 as well as black polythene over traditional practices.

Post-harvest management

Fresh vegetables account up to 95% of moisture which determines useful quality traits like weight, sheen and texture in one way but high moisture content also make products susceptible to drying and microbial attack. Both qualitative and quantitative losses ranging from 20-50%, have serious economic repercussions in fresh produce. Harvest and post-harvest losses of major

Food trap for fruit fly management

vegetables like onion (8.20%), tomato (12.44%), cabbage (9.37%), cauliflower (9.56%), garden pea (7.45%), potato (7.32%) and mushroom (12.5%) has been recorded. Profitable value-added products of tomato (pulp, puree, paste, ketchup, soup, sauces, juices, flakes, powder, dehydrated and canned products), chilli (sauces, powder, pickle), potato (wafers, chips, boiled, fried, baked, roasted, steamed and even in several pressed forms such as French fries, chips, papad, flakes, dice, cubes, granules, flour, and canned potatoes), garden peas (frozen and dehydrated form), bitter gourd (chips, powder, juice, pickles), bottle gourd (juice, instant kheer mix), carrot (powder, juice, flakes, candy, halwa, grits, soup, dahlia, baby food and canned carrot), ginger (paste, candy, preserve, pickle, chocolate, beverages, juice, powder, oleoresin, zinger tea, ice cream), onion (flakes, powder) etc. are more in demand.

Integrated pest management

Insect pests cause an yield loss of 33-40%. Growers relay on chemical control as first choice. Around 13-14% of total pesticides used in the country are applied on vegetables. Parasitoids like *Apanteles taragamae* and *Therophilus javanus* both effectively managed *Maruca vitrata* (legume pod borer), *Diaphania indica* (cucurbits pest) and *Thala flavoorbitalis* (eggplant fruit and shoot borer). As plant protection measure, application of neem oil/neem seed kernel extract (4%), *Trichoderma*, *Jeevaamrit* and *Panchagavya* are effective and safe for vegetable crops. The number of predators, viz. spiders in cowpea and *Coccinellids* in cabbage survives and multiply significantly in organic field.

Integrated disease management

Crop rotation with cereals reduce wilt of pea. Apply *Trichoderma* powder @ 5 kg/ha in soil within a week of ploughing of green manure crops is beneficial. Soil solarization by mulching polythene sheet prior to planting of eggplant and tomato reduced Verticillium

wilt by 25-95%. Biological seed treatment by priming on seed, soaking the seeds, seedling dipping, dry powder treatments etc. are helpful. Treatment of *Trichoderma* (spore concentration 10^6 to 10^9/ml) @ 5-8 g/kg of seeds or 10-20 g powder per m^2 area in nursery bed is essential. Green manuring of sunhemp along with soil application of *Trichoderma* @ 3-5 kg/ha, managed most of vegetable diseases. Foliar spray of *Aspergillus niger*-V isolate, control *Alternaria* blight and die-back/Anthracnose of chillies.

SUMMARY

Adoption of newly developed high-yielding, bio-fortified, and abiotic and biotic stress resistance varieties/ hybrids along with good agricultural practices will be suitable for climate resilient vegetable cultivation. The use of grafts, natural resources, organic matter, water-use efficiency, appropriate weed management and need based application of major and minor nutrients are essential steps for high yield and quality produce. Ensuring the productivity and sustainability, progressive increase of organic matter lead gradually to commensurate increase in soil fertility. Greater investment in research and development (R&D) of climate-resilient vegetable cultivation could provide high marginal payoffs in terms of generating new sources of economic growth and will help in catching international trade.

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