Research Highlights - Vegetable Improvement

Institute Project 1: **Improvement of Cucurbitaceous Crops for Stress Tolerant, Yield and Quality Traits**

- **High-Yielding Varieties Released**: Developed Kashi Godavari (bottle gourd, 51.77 t/ha), Kashi Priya (56.75 t/ha), and Kashi Arpita (bitter gourd, 28-30 t/ha) with 35-50% yield improvement over check varieties.
- **Superior Hybrids Across Seven Crops**: Identified high-performing hybrids including bottle gourd (10.25 kg/plant), watermelon (12.1 kg/plant), pumpkin (9.31 kg/plant), and muskmelon (4.50 kg/plant) demonstrating significant productivity gains.
- **Disease Resistance Traits**: Successfully developed germplasm with gummy stem blight resistance in bottle gourd (VRBG-96, 2% PDI), virus resistance in bitter gourd, and ToLCNDV resistance in muskmelon (VRMM-134-1).

Institute Project 2: Improvement of Okra for Stress Tolerance, Yield and Quality Traits

- **High-Yielding Hybrid Development**: Developed five promising okra hybrids (VROH-24-1 at 195 q/ha, VROH-24-6 at 186 q/ha, VROH-24-7 at 185 q/ha) with standard heterosis of -10.30-19.16% and yields 25-35% higher than commercial check varieties, with three hybrids (VROH-22-14, VROH-22-18, VROH-22-24) showing consistent performance across three years (2022-2024).
- **Specialized Germplasm Development**: Identified dwarf okra genotypes (VRO-200 and VRO-201 with 155-160 q/ha) resistant to YVMV and OELCV, export-oriented lines/hybrids (130-170 q/ha), and characterized six wild-derived amphidiploids (VRAMPD-1, VRAMPD-2, VRAMPD-4, VRAMPD-7, VRAMPD-11, VRAMPD-12) with dual resistance to YVMV and ELCV from wild species germplasm.
- **Cytogenetic Resources for Breeding**: Maintained comprehensive germplasm of 815 cultivated and 184 wild relative accessions, and characterized genetic male sterile (GMS) lines with stable 1:1 sterile-fertile segregation for hybrid seed production, facilitating sustainable okra breeding programs.

Institute Project 3: Improvement of Solanaceous Vegetable Crops for Stress Tolerance, Yield and Quality Traits

- **High-Performing Tomato Hybrids Across Seasons**: Developed superior tomato hybrids with exceptional yields—winter season VRTH-24-33 (1304.16 q/ha), summer season VRTPH-23-1 (616.6 q/ha), and rainy season VRTH-21-21 (443.33 q/ha)—with 40-85% yield improvement over commercial checks; identified two processing varieties Kashi Shreshth and Kashi Daksh with ToLCV resistance and enhanced processing traits (lycopene 4.06-4.68 mg/100g).
- **Stress-Tolerant and Disease-Resistant Germplasm**: Identified brinjal genotypes with multiple disease resistances including bacterial wilt (Kashi Manohar, Kashi Sandesh), fusarium wilt (Kashi Modak, Kashi Uttam), and fruit/shoot borer tolerance; developed high-temperature tolerant brinjal genotypes (Kashi Utsav: 557.2 q/ha) and processing tomato lines (EC-620456: 5.9 ° Brix) for climate-resilient cultivation.
- **Advanced Molecular Breeding and Gene Discovery**: Conducted GWAS analysis on 100 Capsicum accessions revealing 16,745 SNPs and 34 significant SNPs within 28 QTL regions; identified novel candidate genes for chilli leaf curl virus resistance (Formin-like protein 3), anthracnose resistance, and fruit quality traits, validating genes for 11 traits through molecular approaches.

Institute Project 4: Improvement of Leguminous Vegetable Crops for Stress Tolerance, Yield and Quality Traits

- **High-Yielding Pea Varieties with Multiple Disease Resistances**: Released two pea varieties—Kashi Dhanvi (115-120 q/ha, TSS 13.7 ° Brix) and Kashi Mator 343/Kashi Trishakti (125-135 q/ha) with resistance to powdery mildew, downy mildew, and rust; developed 16 export-quality pea genotypes (VRP23-7, VRP23-12, VRP23-4) meeting international standards for pod length, sweetness, and freezing quality.
- **Climate-Resilient Legume Germplasm**: Identified heat-tolerant pea genotypes (VRPE-29, VRPE-30, Kashi Udai, VRPE-100 with 45-60 g/plant under 28-32° C); cowpea varieties for low-temperature cultivation (Kashi Nidhi, Kashi Vishan, VRCP23-1: 160-190 g yield); and yard long bean genotypes (VRCPP23-5: 524.33 g yield, VRCPG24-2: 481 g yield) demonstrating stress adaptability across seasons.

- **Quality Enhancement and Nutritional Optimization**: Evaluated antinutritional factors across 23 legume genotypes identifying varieties with acceptable levels—Kashi Rajhans (phytate 1.32 mg/g, saponin 0.74 mg/g, TIA 19.75); screened for disease resistance (cowpea golden mosaic virus VRCP-262A with zero infection); and developed dual-purpose French bean genotypes (VRFBP 44, Kashi Baigani) combining pod and grain quality traits for diverse markets.

Institute Project 5: Improvement of Cauliflower & Carrot for Stress Tolerance and Quality Traits

- **Climate-Resilient Cauliflower Germplasm for Multiple Seasons**: Developed early-maturing cauliflower genotypes for warm conditions (VRCF-307, VRCF-306, VRCF-305: 350-450 g curds at 28-30° C) and cooler seasons (VRCF-11, VRCF-12, VRCF-111: 425-500 g at 24-28° C); created novel high-temperature tolerant May-curding cauliflower segment (VRCF-306, VRCF-318: 96% curding frequency at 38-45° C); released VRCFH-1 CMS-based hybrid recommended by AICRP-VC with yields of 160-190 q/ha across temperature zones.
- **Biofortified Rainbow Carrot Development**: Developed tropicalized orange carrot (VRCAR-135, VRCAR-132, VRCAR-135-4 with 6.50-8.25 mg beta-carotene) and innovative rainbow carrot with four pigments (anthocyanins 15-20 mg, beta-carotene 2.75-3.50 mg, lycopene 3.50-4.50 mg, lutein 0.20-0.30 mg per 100g FW) for enhanced nutritional value and consumer appeal.
- **Hybrid Carrot Varieties and CMS Line Development**: Released VRCARH-2, a red carrot CMS-hybrid recommended by AICRP-VC with high lycopene content (7.40-7.60 mg/100g FW), attractive root color, 350-375 q/ha yield, and 90-100 days maturity; developed 7 stable CMS lines across multiple colors (red, orange, black, yellow, rainbow) with 2 registered with INGR and others submitted for registration, enabling sustainable hybrid seed production.

Institute Project 6: Biotechnological Interventions for Management of Stresses, Yield and Quality in Vegetable Crops

- **CRISPR/Cas9 Genome Editing for Disease Resistance**: Developed ToLCV-resistant tomato lines through viral genome targeting (13 T_0 transgenic

plants with Cas9 confirmed in 12 events) and Fusarium wilt resistance in Kashi Aman (5.62% transformation efficiency, 42 responding shoots); created ChiLCV-resistant chilli (Kashi Anmol) with CaPelota gene editing (1220 explants transformed, 8 rooted plants); engineered muskmelon (Kashi Madhu) for delayed fruit ripening and extended shelf-life targeting CmNAC-NOR and CmACO-1 genes (83 responsive shoots from 252 explants).

- **Advanced Molecular Breeding and Genomic Resources**: Completed whole genome sequencing of Indian bean/Dolichos (Kashi Haritma) with 98.8% genome completeness (449 MB, 11 chromosomes) and NCBI accession assigned; developed brinjal RPN-10 gene edited lines for phytoplasma resistance (13 shoots regenerated); engineered cucumber for powdery mildew resistance via CsMLO-8 manipulation (48 putative plants generated through in-planta transformation).
- **Microbe-Mediated Stress Mitigation and Biofortification**: Developed bacterial consortia formulations (BC6 and AzoBC) in liquid, powder, and granule forms for enhanced plant growth and nutritional content; created metabolite biomarker-based biostimulants (GrowVit, GrowVit+, SalAscoVit) showing significant improvements in tomato (increased lycopene, carotenoids, fruit weight); valorized vegetable waste into compost enriched with N- and P-solubilizing bacteria for sustainable crop improvement.

Institute Project 7: Seed Management Perspectives in Vegetable Crops

- **Comprehensive Seed Production and Distribution**: Produced total vegetable seeds of 12,885.84 kg covering 22 crops and 49 ICAR-IIVR varieties; generated TL seeds of 7,142.94 kg (open-pollinated varieties) plus 120.92 kg hybrid seeds (16.72 kg at IIVR + 104.20 kg at Sargatia); maintained breeder seed stock of 5,142.94 kg ensuring seed security and availability for farmers across diverse vegetable crops.
- **Seed Enhancement and Stress Mitigation Technologies**: Developed seed priming protocols for salinity tolerance—ascorbic acid (1 mM) for chilli (EC-519697 at 150 mM) and mannitol (20 mM) for cowpea (Kashi Nidhi at 200 mM); categorized 70 brinjal genotypes for salinity tolerance using fuzzy

comprehensive evaluation, identifying 54 salt-tolerant and 10 highly salt-tolerant genotypes for future breeding.

- **Standardized Seed Germination Protocols and Pollination Management**: Established crop-specific germination testing protocols for mustard, moringa, basella, and chenopodium following ISTA guidelines; resolved chenopodium dormancy with 66% germination using scarification + water flotation + heat treatment; optimized cauliflower seed yield through pollination management (15% sucrose + boric acid + $CaCO_3$ + KNO_3 at 3 daily sprays achieving desiccation tolerance at 49 DAA and quality seed at 63 DAA).

Institute Project 8: Maintenance and Promotion of ICAR-IIVR Varieties/Hybrids

- **Comprehensive Germplasm Conservation and Sharing**: Maintained 6,718 accessions of 42 vegetable crops (3,972 major vegetables and 2,746 minor vegetables) including major crops like tomato (503), okra (815+184 wild relatives), chilli (410), pea (382), and brinjal (384); shared 498 accessions of 16 vegetable crops with 31 research organizations, including 103 okra accessions shared with 4 institutes and 71 tomato accessions distributed to 8 institutes for research advancement.
- **Field Promotion and Farmer Reach**: Successfully promoted ICAR-IIVR varieties through 10 KVK centres covering multiple crops—chilli (Kashi Ratna, IIVRC-18057), okra (VROH-21-7 hybrid), winged bean (Kashi Rudraksha, Kashi Annapurna), brinjal (IVBHR-19), and tomato varieties; demonstrated carrot (Kashi Arun, VRCARH-2), radish (5 varieties), spinach beet (Kashi Baramasi), and cauliflower varieties; maintained and promoted 15+ minor vegetables including basella, amaranth, indian bean, moringa, faba bean, and cluster bean.

Institute Project 9: Enabling Climate Resilience and Ensuring Food & Nutritional Security through Genome Editing in Horticultural Crops

- **Multi-Crop Genome Editing for Disease and Stress Resistance**: Developed CRISPR/Cas9-edited tomato lines targeting ToLCV resistance through viral genome targeting (Pelota gene: 13 T_0 transgenic plants with Cas9 confirmed

in 12 events) and Fusarium wilt resistance (TPL gene: 1200 explants transformed with 5.62% efficiency, 42 responsive shoots); engineered chilli (Kashi Anmol) for ChiLCV resistance via CaPelota targeting (1220 explants transformed, 15 shoots, 8 rooted plants); created cucumber lines for powdery mildew resistance (CsMLO-8 gene: 48 putative plants via in-planta transformation).

- **Quality Enhancement and Post-Harvest Traits through Genome Editing**: Engineered tomato for enhanced total soluble solids (TSS) through SlINVINH1 and SlVPE5 genes (2733 explants, 147 shoots regenerated, 5.37% transformation efficiency); developed muskmelon (Kashi Madhu) for delayed fruit ripening and extended shelf-life by targeting CmNAC-NOR and CmACO-1 genes (252 explants, 83 responsive shoots); completed whole genome sequencing of Indian bean/Dolichos (98.8% genome completeness, 449 MB, 11 chromosomes, NCBI accession assigned).

Improvement Division: Publication, Knowledge Dissemination and Institutional Recognition: Published 80 research papers (39 in high-impact journals with >6 NAAS score), 27 extension folders, 44 popular articles, 23 book chapters, 11 technical bulletins, and 14 radio/TV talks; received 38 honour and recognition including 1 NAAS Fellowship; registered unique germplasm (wild tomato WIR3928 for *Alternaria solani* resistance); popularized Kashi Parwal-141 through multiple digital and print media platforms for farmer adoption.