speci c glycosylases or other enzymes involved in plant-speci c post-translational modi cations. Other plants have been produced that express glycoproteins which are sialylated and O-glycosylated

advantage of being able to self-assemble into virus-like particles [42]. Lastly, Webster et al. [37] expressed the malarial antigen PyMSP4/5 in leaves using the same deconstructed TMV vector outlined above. Malarial antigen expressed reached levels up to 10% of total soluble protein or 1-2 mg/g of fresh weight produced. Moreover, the antigen retained its immunogenicity following long-term storage at ambient temperature within freeze-dried leaves. Mice that were fed this plant-derived malaria antigen along with a mucosal adjuvant, produced malaria-speci c antibodies, supporting the concept that large quantities of malaria vaccine can be produced and stored using this TMV-based production system.

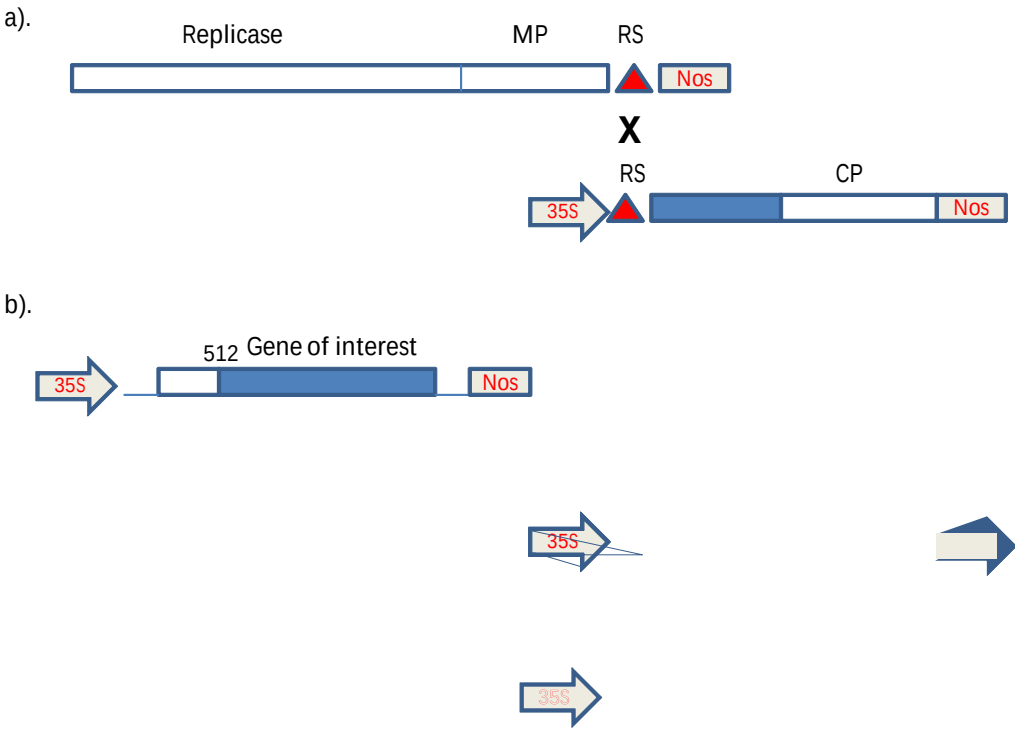
e deconstructed TMV expression system has also been employed as a potential treatment for various forms of cancer, such as Non-Hodgkins Lymphoma (NHL). NHL is currently the h highest cause of death in North America, and involves the uncontrollable proliferation of degenerate B-cells, which accumulate in the lymph nodes, bone marrow and other tissues. Degenerate B-cells of each individual NHL patient express a unique idiotype, which can be rapidly and inexpensively expressed in plants using a TMV-based virus expression vector agroin ltrated into tobacco leaves. Using this strategy, adequate amounts of lymphoma vaccine can be rapidly and inexpensively produced for each patient. Plant-made vaccines expressed in this fashion o er a powerful short-term therapy to keep tumors in check [43].

A novel launch vector, constructed by Musiychuk et al. [44] and composed of TMV-based expression vector sequences harboured on the *A* binary vector pBI121 has been utilized for vaccine production. Using this expression system, multiple ssDNA copies of target sequences are released upon introduction into plant tissue. One hundred milligram quantities of protein per kilogram of plant tissue have been generated in less than a week using this expression system. Vaccines produced using the launch vector system include the oncogenic E7 protein of HPV, the H5N1 in uenza virus HA and NA domains, and the F1 and V antigens of . . ese vaccines successfully protected against infection in animal models [45-47].

Cowpea mosaic virus

Among the other plant RNA viruses that have been investigated for their potential to produce biopharmaceutical proteins, Cowpea Mosaic Virus (CPMV) has been utilized extensively [28]. CPMV has a bipartite genome, replicates well in host plants, can readily incorporate vaccine epitopes onto exposed loops on the surface of its icosahedral virion, and can easily be extracted and puri ed from plants. Recombinant virus particles expressing foreign epitope sequences produce virus yields similar to that of wild type CPMV infection, and many of the epitopes which have been displayed on the surface of CPMV have been able to evoke strong immune responses [24]. Heterologous full-length proteins have also been expressed using CPMV as an expression vector system, such as the 2A protein of Foot and mouth disease virus. In this and other cases, the foreign protein has been expressed as a fusion along with the CPMV coat protein or movement protein, joined by an integral proteolytic cleavage site to allow the target protein to be released [48].

A disabled and replication incompetent version of RNA-2 of CPMV has recently been developed into a novel expression system



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