



**STRATEGY ON BREEDING VEGETABLES
IN BHUTAN
2024-2033**



**DEPARTMENT OF AGRICULTURE
MINISTRY OF AGRICULTURE AND LIVESTOCK**

2023



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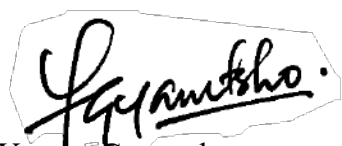
Foreword

Agriculture sector plays a crucial role in national food security and nutrition. One of the most significant sub-sectors offering better opportunities to achieve the Ministry's vision and goals is horticulture. Thus, the Department of Agriculture continues to give importance on developing new vegetables varieties. However, there exist many unforeseeable challenges in the research and development of vegetables including complex production systems, occurrence of pests and disease, impacts of the climate change and market constraints. Bhutan relies on imported vegetable varieties, which are often not well-adapted to local climactic conditions. The absence of dedicated breeding efforts hinders the development of locally-adapted, high-yielding, and disease-resistant varieties. In addition, the consumers seek high-quality vegetables with desirable traits like taste, appearance, and shelf life.

Numerous studies have shown that locally bred crop varieties often thrive well in their specific agro-ecological conditions. The sociocultural factors including consumer preference for flavor and color are accounted during the development of new and improved varieties. As a result, the adoption rate of locally produced varieties tends to be high since it can optimize the genetic variation, focusing on specific adaptations favourable to the local conditions.

Recognizing the importance of quality seeds for agricultural growth, the Department of Agriculture has developed the Vegetable Breeding Strategy (2024-2033) which aims to support the Ministry's vision of achieving national food and nutrition security and ensuring the availability of sufficient, accessible, and affordable vegetable varieties for Bhutanese farmers. This strategy envisions a robust vegetable breeding program in Bhutan, leading to the development of locally- adapted, high-yielding, disease-resistant, and high-quality vegetable varieties. By implementing this strategy, Bhutan can achieve self-sufficiency in vegetables, improve food security, and contribute to the social well-being.

It is my sincere hope that the Vegetable Breeding Strategy becomes a guiding document for the breeding of vegetables in achieving vegetable self-sufficiency and for sustainable and innovative practices that will enhance agriculture productivity.



Yonten Gyamtsho

DIRECTOR

ABBREVIATION & ACRONYMS

ARDC:	Agriculture Research and Development Centre
DoA:	Department of Agriculture
FYP:	Five Year Plan
MoAL:	Ministry of Agriculture and Livestock
NBC:	National Bio-diversity Centre
NCOA:	National Centre for Organic Agriculture
NSB:	National Statistics Bureau
NSC:	National Seed Centre
WVC:	World Vegetable Centre
WHO:	World Health Organization

Contents

1. INTRODUCTION.	1
2. THE CURRENT STATUS OF VEGETABLE BREEDING IN BHUTAN.	2
3. RATIONALE FOR VEGETABLE BREEDING STRATEGY.	2
4. OBJECTIVES.	4
5. PRIORITY AREAS FOR VEGETABLE BREEDING.	4
5.1 ESTABLISHMENT OF FOCAL VEGETABLE BREEDING CENTRES.	4
5.2 GERMPLASM.	5
5.3 PLANT BREEDING CAPACITY BUILDING.	5
5.4 IDENTIFICATION OF VEGETABLE CROPS TO INITIATE BREEDING WORK.	6
5.5 BREEDING METHODOLOGY.	6
5.5.1 Selection.	6
5.5.2 Hybridisation.	6
5.5.3 Inter-specific Hybridisation.	7
6. SEED PRODUCTION OF VEGETABLES.	8
7. TIMEFRAME.	8
8. FUND MOBILIZATION.	8
9. LEGAL AND POLICY FRAMEWORK.	8
10. REPORTING.	9
11. CONCLUSION.	9

1. Introduction

Vegetables play a significant role in human nutrition, especially as sources of vitamins, minerals, dietary fibre and phytochemicals. In much of South and South East Asia, dietary deficiencies of iron and vitamin A are major health problems, resulting in hundreds of deaths each year. The World Health Organisation (WHO) has recommended a daily intake of at least 240 g of vegetables. However, currently at 84% self-sufficient in 18 major vegetables, Bhutan needs to increase their production to meet the target of WHO's recommended daily intake of vegetables.

There are many factors that impede the production to achieve 100% self-sufficiency. Amongst others, the factors are lack of suitable varieties of vegetables, outbreak of pests and diseases, and less knowledge of farmers on production technologies are the main challenges in achieving self-sufficiency in vegetables in the country. In order to increase vegetable production in Bhutan to achieve its self-sufficiency, there is a strong need to have an adequate number of vegetable varieties suitable for cultivation in the Bhutanese climatic conditions. Breeding programme in vegetables is necessary to develop resistance to diseases and pests, resilient to drought and temperature extremes, and to improve quality factors. Plant breeding can also be used to help adapt crops to new locations throughout the world, thereby improving food security and supporting local and regional food systems. Vegetable breeding has to address and satisfy the needs of both the growers and the consumers. The general objectives for growers are good uniformity, yield, disease and pest resistance, and tolerance to abiotic stresses. The main objectives for consumers are quality, appearance, shelf life, taste, and nutritional value.

Quality in vegetable crops, in contrast to field crops, is often more important than yield. For growers to be able to sell their vegetables, cultivars must be accepted by the market. Improved genotypes developed by plant breeding remain pivotal to national food security. In the wake of declining agricultural resources and the stresses generated by climate change, plant breeding is expected to make larger contributions in increasingly shorter time frames. Farmers will have access to better varieties which means that their economic development will be enhanced. The Ministry's vegetable commercialization programme has re-emphasized the need for the initiation of breeding in vegetable crops for meeting annual production targets as well as domestic demand in the wake of ban on some selected vegetables. Department of Agriculture has accorded high priority on vegetable production in realising the Ministry's long-term vision of National Food and Nutrition Security. Consequently, vegetable programme is expected to *contribute to this vision and achieve the goal of food self-sufficiency, which can be realised through appropriate planning approach, strategies and implementation.*

2. The Current Status of Vegetable Breeding in Bhutan

Although 114 varieties (99 open pollinated and 15 hybrids) of 32 different types of vegetables are currently in cultivation in Bhutan, formal breeding work in vegetables has not been initiated yet. However, some cultivars of landraces and open-pollinated vegetables have existed for long periods in the country outside the professional plant breeding circle because they have been kept alive within communities by succeeding generations of farmers. The vegetable cultivars like *Paro local* in brinjal, *Sha Ema*, *Boegop Ema* and *Urka Bangla* in chilli, *Shabi Genchu* in cucumber and *Rangthang Brumsha* in pumpkin are some examples of vegetable cultivars developed and kept alive by the farming communities in Bhutan. Unfortunately, active seed savers are becoming more and more a minority among the vegetable growers and many farmers are no longer saving vegetable seeds due to commercialised market and the professionalization of the seed sector. This is a threat to vegetable genetic diversity. So, initiation of formal breeding work in vegetables is urgently required in Bhutan in order to increase the current narrow genetic base of vegetable germplasm in the country and to achieve food and nutritional security.

From the early 1990s the Ministry through the Research and Development Centres gave major emphasis on introduction and evaluation of new vegetable crops, such as, cabbage, cauliflower, broccoli, tomato, asparagus, etc., which led to the adoption and release of a number of new crops for general cultivation by the farmers in the country. More than 100 varieties of vegetables have been released for cultivation by the farmers with highest number of varieties of beans and cabbage (11 each) tomato (9) and radish (8). Seeds of these varieties which are released through the Variety Release Committee (VRC) are maintained and produced by the Seed company such as the National Seed Centre and Bhutan Alpine Seeds. The foundation or the basic seed are maintained at the releasing research centres.

With the start of commercialization of vegetables in the country, seeds companies, such as, the National Seed Centre, Bhutan Alpine Seeds and Rewa Seeds have started importing hybrid seeds. Importing agency, including the NSC, provides seed sample to the Research Centre for initial evaluation. A rapid testing for a season or two of the hybrids for their adaptive ability and suitability is then conducted by research centres before recommending them to any grower.

3. Rationale for Vegetable Breeding Strategy

From the early 1990s the Ministry through the Research and Development Centres gave major emphasis on introduction and evaluation of new vegetable crops, such as, cabbage, cauliflower, broccoli, tomato, asparagus, etc., which led to the adoption and release of a number of new crops for general cultivation by the farmers in the country. More than 100 varieties of vegetables have been released for cultivation by the farmers with highest number of varieties of beans and cabbage (11 each) tomato (9) and radish (8).

The open-pollinated varieties are produced by the seed companies, the National Seed Centre and Bhutan Alpine Seeds, while currently, most of the hybrid vegetable seeds requirement in Bhutan is met through import primarily due to the lack of varieties developed in the country. Further, Bhutan imported about 1,000 kgs of hybrid vegetable seeds in 2021 worth Nu 20 million. This leads to draining of currencies from the country. The growth of local cultivars is anticipated to eventually reduce imports.

The varieties introduced in Bhutan from elsewhere are bred for specific geographical adaptation and those varieties may not perform well in our local climatic conditions. Research on various crops across the world shows that locally developed crop varieties often do well under the local agro-ecological conditions. This is because such varieties are developed to fit in the local soil and climatic conditions. Additionally, the adoption rate of locally produced varieties is high since socio-cultural aspects of local consumers, such as taste and colour, are considered while developing the varieties. Breeding for specific adaptation can maximize the contribution of landrace genetic resources that are evolved in favourable local environments. Breeding for resistance is valuable tool for controlling pest and disease. The use of pesticides that Bhutan imports can be reduced by breeding of vegetable for resistance to pests and diseases. Breeding resistance varieties are of paramount importance to organic agriculture where pest and disease control for the crops is the biggest challenge.

There is a paradigm shift in vegetable seed production system from conventional methods to breeding by private seed companies worldwide. However, in Bhutan we have not yet started production of our own hybrid seed. ARDC Wengkhar initiated breeding of tomato through crossing with the aim to develop varieties resistant to late blight. This however has not been continued. ARDC Samtenling has initiated chilli hybridization against *Phytophthora wilt*. Besides these, no other activities have been undertaken. In Bhutan, facilities to conduct scientific breeding are lacking in the research centre. A well-equipped laboratory must be set up. The scientific breeding must be accorded high priority and staffed d by competent human resources in the ARDCs and the NCOA.

The improved varieties are introduced in the country and evaluated for several years under different agroclimatic conditions. These varieties are than released through the Variety Release Committee (VRC) for production in the country. While the basic seeds are maintained by the introducing research centres, seeds for commercial production are produced by the Seed company such as the National Seen Centre and Bhutan Alpine Seeds. Over time, it is discovered that the majority of OPVs are degenerating and losing quality. Farmers' complaints about the OVPs' subpar seed have become relevant.

In order to meet the quality seed demand, seeds companies such as National Seed Centre, Bhutan Alpine Seeds and Rewa seeds imports hybrid seeds. These varieties are evaluated for one to two years in the research centres for suitability and released for production through the Variety release committee. Although the system has aided to increased vegetable production,

the supply of hybrid seeds over a long period has become unreliable due to change in the priority of supplying Seed Company.

4. Objectives

The purpose of this strategy is to outline the development of a set of core guiding principles for the breeding strategies and techniques for the development of varieties that are adapted to local farming systems in Bhutan. The following are the main objectives:

- To develop vegetable varieties that are pest and disease resistant and climate resilient suitable under Bhutanese farming system.
- To exploit the local gene pool diversity to develop suitable varieties for Bhutanese agro-ecosystem under changing climatic conditions
- To generate knowledge, information and technology on vegetable breeding.
- To collect, characterise and identify the desirable traits in native landrace and wild vegetables for use in breeding programmes.
- To equip agricultural researchers with theory and techniques of vegetables breeding to create new vegetable varieties that suit local needs and situations.
- To initiate breeding of vegetables in Bhutan for development of varieties that is demand-driven and responsive to emerging needs and challenges.
- To promote and strengthen collaboration on vegetable breeding within and outside Bhutan (e.g. WVC- World Veg Centre).

5. Priority Areas for Vegetable Breeding

5.1 Establishment of Focal Vegetable Breeding Centres

Presently, there are four Agriculture Research and Development Centres (ARDC) with mandates for agriculture research and developmental activities. Among 4 ARDCs in Bhutan, one National Centre for Organic Agriculture (NCOA), Yusipang shall be designated as a focal centre for breeding of vegetables as the centre is focal for veg program. Breeding of vegetables shall be conducted in all the existing ARDCs but the facility for molecular breeding work shall be established at NCOA Yusipang at the start of the breeding programme.

There shall be cooperation among ARDCs, National Seed Centre, National Biodiversity Centre and the Bhutanese Private Seeds companies for sharing of resources (e.g. germplasm, protocols, etc.) and technical expertise on vegetable breeding. All plant breeders must be able to work effectively as a member of a team. Teamwork is increasingly becoming important in research, where the breadth of expertise required for success is well beyond the scope of any individual member. Strengthening the network within the breeder community, regular exchange of knowledge and coordination on breeding works can give rise to great potential for synergies.

5.2 Germplasm

Germplasm is the basic requirement for development of any crop variety. The fundamental objective of collecting plant genetic resources is to capture the maximum amount of genetic variation in the smallest number of samples. The objectives of the germplasm collection are to characterise landrace cultivars of vegetables (germplasm inventory), identify the desirable traits and generate information and conservation them for use in breeding programs. Germplasm collecting is expensive. Therefore, we should review the past collections of the crop before embarking on a new collection trip. Further, many wild vegetable species harbour genes meant for providing resistance to disease and also quality (shelf-life, taste, etc.). Thus, the wild vegetable species can be used for introduction of qualitative and quantitative traits in cultivated parental lines in the development of hybrid vegetables.

5.3 Plant Breeding Capacity Building

Currently, the Department of Agriculture has a critical shortage of skilled breeders. Plant breeding is an activity that requires a considerable amount of knowledge and skill to support the lengthy processes of research on development of new crop varieties. Plant breeding is both an art and a science, where the art encompasses careful observations of plant behaviour in the field and to some extent, the choice of parents for crosses, and the science relates to knowledge of genetics, physiology, pathology, statistics, and other disciplines so that they can ensure they create the best possible varieties suitable for specific requirement. Raising the capacity of plant breeding at national and regional levels requires the training of agriculture researchers and the development of an integrated set of capabilities to build and sustain effective regional and national plant breeding programs. Thus, both short-term and long-term training of the researchers on plant breeding are important for initiation of the plant breeding crop in the country.

The Department of Agriculture should support training in plant breeding and related scientific capacities of the relevant staff. Capacity building should be defined and carried out in a systematic manner that takes into account the unique needs of the country. Both the short-term and long-term, and in-country and ex-country training programs will be essential for marker-assisted selection (MAS) breeding activity. In-country training has advantages in cost, relevance, and reduced disruption to workplace ties. A pool of staff identified at all ARDCs will be trained on the breeding of vegetables, who will lead and conduct research and developmental activities in their respective region. Networks and linkages with international organizations shall be established for MAS breeding programmes.

Agriculture research system in developing countries generally considers agriculture biotechnology as a hi-tech tool relevant only to industrialized nations. However, biotechnology offers great potential to contribute to sustainable agricultural growth, food security and poverty alleviation in developing countries. Thus, Bhutan should also prioritize capacity development

for biotechnology research, especially for genetic characterization of traditional and wild vegetable genetic resources.

5.4 Identification of Vegetable Crops to Initiate Breeding Work

The best strategy for plant breeding and crop improvement is to control pollination. Thus, to initiate crossing and hybridization works, self-pollinated vegetable crops (like tomato, chilli, beans, etc.) are option because they can be selected from their relatively small population. On the other hand, cross-pollinated plants require special efforts to inbreed these species into a stable variety due to transgressive segregation. Another good approach is to pick vegetable crops that historically have been grown in our region and have the potential to produce well in our own climatic condition. It is also a good idea to breed for varieties that have resistance to heavy disease or pest pressures in our growing fields.

5.5 Breeding Methodology

Breeding of vegetable crops involves different breeding methods and selection procedures. The choice of specific breeding and selection methods depends upon the reproduction and natural breeding system of the crops. A list of possible breeding methods in vegetable crops that can be adopted in the country is given below:

5.5.1 Selection

Selective breeding involves selecting parents having desirable characteristics that can be inherited by their off springs.

Pure line selection

Pure-line selection involves selecting and breeding progeny from superior organisms for a number of generations until a pure line of organisms with only the desired characteristics has been established.

Mass selection

Mass selection involves the selecting of a group of individuals from a population on the basis of their similar phenotype in an attempt to improve the performance of the population for that character or characters. In the mass selection procedure, there is no progeny test (in contrast to pure line selection) but the selected population is usually evaluated against the original unselected population to gauge the effectiveness of selection.

5.5.2 Hybridisation

Intra-specific hybridisation

Intra-specific hybridisation is a cross between the two varieties of the same species. The crosses are made between the plants belonging to two different varieties of same species.

Pedigree method

It involves the hybridisation of two parents, one usually a commercial variety and the other chosen because of a particular superior attribute. The breeder aims to incorporate this attribute in a genetic combination that is at least equal to the commercial variety in all characters and possessing the attribute of the donor parent.

Bulk method

The bulk method of breeding involves hybridising two chosen parents and growing the F₂ and subsequent generations until the F₆ generation in bulk populations as field plots in successive years.

Single seed descent method

Single seed descent (SSD) is used in the breeding of self-pollinated plants by advancing lines from generation to generation through the use of a single seed from the progeny of each plant (rather than single plant and progeny row selection as in the pedigree method).

5.5.3 Inter-specific Hybridisation

The crosses are made between two different species of the same genus.

Backcross method

A crossing between a F₁ hybrid or its segregating generation with one of its parents is known as Backcross. The hybrid and its progenies in the subsequent generations are repeatedly back crossed to one of their parents.

Multi-lines varietal breeding

Multiline varieties are mixtures of several pure lines of similar height, flowering and maturity dates, seed colour and agronomic characteristics, but having different genes for disease resistance.

Population approach

A population approach to breeding involves treating a group of crosses as a single population with the objective of maximising overall genetic improvement through a series of cycles of recombination and selection.

Polyploidy breeding

Polyploidy involves the process of doubling the chromosomes in crop plants. Polyploid organisms often exhibit increased vigour and, in some cases, outperform their diploid relatives in several aspects.

1. Seed Production of Vegetables

The Agriculture Research and Development Centres (ARDC), National Seed Centre (NSC) and private seeds companies are the key agencies involved in vegetable seed research and production programmes in Bhutan. ARDCs or any the agencies involved in developing the varieties shall produce and maintain breeder seeds (for open pollinated varieties) of parent lines (for F1 hybrids). National Seed Centre shall be responsible for production and maintenance of foundation seeds. Certified seed of both open pollinated varieties and F1 hybrids can be produced and sold by National Seed Centre, private seed companies and community seed producers under the close supervision of the National Seed Certifying Agency.

2. Timeframe

Plant breeding requires long-term commitment and resources at regional and national levels that are essential for the development of improved cultivars with increased yields, improved quality and better adaptation to the changing environmental conditions. The breeding of new varieties takes a long time depending on the vegetable species. From the start of a new breeding program to the first marketable variety takes more than 10 years. Anticipated developments must therefore be recognized and taken into account in a timely fashion. Thus, the suggested timeframe for vegetable breeding strategy is 2024-2033.

3. Fund Mobilization

An effective strategy on crop improvement requires an active investment from the government. The government shall, through the annual budgets, provide adequate fund for vegetable breeding activities in Bhutan. The Ministry of Finance allocates the agriculture research budget amongst the various research institutions under MoAL based on priority needs and research work plans (five-year and annual). The budget for vegetable breeding shall be based on annual work plan and drawn from the annual budget allocation to each ARDC. Further, projects to support vegetable breeding shall be proposed to various relevant funding sources.

Allocate RGoB budget codes and sub-codes to research in general and vegetable breeding in particular in order to ensure focused funding on vegetable breeding, highlight its importance, and increase the accountability of breeders. For research on breeding of vegetables, all ARDCs shall create the activity along with budget heads and allocate budget for vegetable breeding activity into their annual budgeting system.

4. Legal and Policy Framework

Legal and policy frameworks are necessary for the successful implementation of vegetable breeding research strategies. The vegetable breeding strategy shall be implemented in line with existing government policies and legal frameworks like “The Seeds Act of Bhutan, 2000” and

“The Seed Rules and Regulations of Bhutan, 2006”. Legal and policy frameworks are required in regulating the process of breeding and certification of vegetable varieties in the country. A properly functioning administration and monitoring system with access to the relevant information is required for implementation and monitoring of vegetable breeding activities in the country.

The “Plant Breeders Rights” as laid down in “The Biodiversity Act of Bhutan, 2003” is required to provide for the protection of new plant varieties in order to promote plant breeding activities that will stimulate, facilitate and improve agricultural research in the country. Plant breeders not only use their own genetic material but also exchange with other breeders, nationally and internationally. There must be appropriate legal framework in Bhutan for international access to and exchange of genetic resources.

5. Reporting

Reporting of all research and development on vegetable breeding activities should be sent to the coordinating centre once a year for compilation, review, planning and reporting purposes. The Focal Centre for vegetable breeding should submit the compiled report and finalized plan and DoA and other relevant agencies on annual basis. A separate forum is needed for presenting research output, findings, and progress and finalisation of future work on vegetable breeding in Bhutan.

6. Conclusion

With this strategy in place, it is expected that research and development on vegetable breeding works in Bhutan is streamlined and boosted. It is also expected that the initiation of breeding work in priority vegetable crops will effectively contribute to the national adaptation against the impacts of climate change on agriculture and ensuring food security, nutrition and income in the long run.

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