DEPARTMENT OF AGRICULTURE
Ministry of Agriculture and Forests

Agriculture Research and Development Highlights 2019-2020

August 2020

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ROYAL GOVERNMENT OF BHUTAN

Agriculture Research and Development Highlights 2019-2020

August 2020

Department of Agriculture
Ministry of Agriculture and Forests
Thimphu, Bhutan

FOREWORD

The Department of Agriculture is pleased to bring out its "Annual Research and Development Highlights" for the fiscal year 2019-20. This annual publication is a concise summary of all major achievements made in research and development by Agriculture Research and Development Centres (ARDCs), Central Programs, Commodity Programs and Support Services within the department. It is an attempt to document the department's progress highlight for the reporting year while also addressing the challenges in pursuit of crop research and production, service delivery, infrastructure establishment and capacity building.

The later part of the reporting year saw the department engage in and put forth a series of initiatives as part of the government's response to mitigate the fallout from the Covid19 pandemic. These shall be included in the following year's report.

This publication strives to collect reports from all agencies within the Department of Agriculture, collate the information, analyse and synthesize them into an abridged version that succinctly presents the progress for the past one year. The highlights are aggregated into different groups of approved programs, and therefore relay the cumulative figure of all major achievements by agencies within the department for the year. It however, is exclusive of the various programs and initiatives under taken by respective dzongkhag.

The reporting format and the style allow for readers to browse through separate sections of interests to get a definitive overview of achievements thereof. Readers are however, encouraged to refer to annual reports of individual agencies for an exhaustive coverage. Individual agencies take out their own separate reports that provide comprehensive coverage of their respective progress.

I commend the Agriculture Research & Extension Division (ARED) and the editor for their diligence in meticulously going through every single report to analyse and take out this single synthesized summary for the department.

With best regards,

Kinlay Tshering (Ms)
DIRECTOR

Table of Contents

LIST OF TABLES

LIST OF FIGURES

SUMMARY

- ✓ The DoA's initiative on winter chilli production has come a long way. Though unhindered supplies to major markets in the winter is still a challenge, three consecutive years of winter chilli commercialization program (2017-2019) saw tremendous increase in both area and production. Overall cultivation expanded from 272 acres in 2017 to 799 acres in 2019. The department has now limited its support to distribution of hybrid seeds while respective dzongkhags are expected to continue the initiative.

- ✓ As part of the initiatives in responses to Covid-19 pandemic, the department in collaboration with Thimphu Thromde and Thimphu Dzongkhag initiated the Urban and Peri-urban Agriculture Farming Program in and around Thimphu for furloughed employees. The program with additional fund from the Food and Agriculture Organization (FAO) involved a total of 22 groups comprising 87 members who were provided with land development services, vegetable seeds/seedlings, organic manure, electric fencing and agriculture tools worth a little over Nu. 0.5 Million.

- ✓ After over four years of nationally coordinated research on 452 heat tolerant maize (HTMA) hybrids, the Department of Agriculture released a new heat tolerant maize variety *Wengkhar HM-1*. This development is expected to contribute significantly in the department's efforts towards ensuring food security, improving nutrition and reducing poverty through increased maize production, and in expanding income generating opportunities at household and community levels.

- ✓ In keeping with its efforts into research and technology development, the Department of Agriculture released two high yielding bean varieties (*Samtenling Semchu-1* and *Bajo Semchumkaap*) following three consecutive years of on-station evaluation at its research and development centres in Samtenling and Bajo. Additionally, the department is presently evaluating around 25 varieties of vegetable across four research and development centres for their performance.

- ✓ The DoA also released a new plum variety *Yusi-prune 1*. *Yusi-prune 1* is one of the most popular of prune-plums which are grown principally for drying and is of mostly European origin. It presents huge potential for commercial horticulture.

- ✓ The reporting year also saw a new banana variety *Samtenling Ngangla 1* being released for farming. An important variety from Israel, this variety is popular for its tolerance to abiotic stresses and for its good quality bunches as well as better keeping quality and shelf life. It can also be easily mass-multiplied through tissue culture.

- ✓ Based on their bio-chemical content, crop suitability and processing potential and in its effort to promote plantation crops, the department released two accessions of tea *Sam Ja 1* and *Sam Ja 2*.

- ✓ Following its introduction in 2015, and the official release of four varieties in 2018, the department has been aggressively promoting quinoa in all 20 dzongkhags, including processing and packaging options. ARDCs and dzongkhags have successfully coordinated the production of 76.96 MT of Quinoa in FY 2019-20. Studies into assessing suitable sowing time for second crop of Quinoa after potato harvest in high altitude areas is complete and technical recommendations are expected soon.

- ✓ Towards nutrition security and in enhancing household income, the department through its research and development centres established 99 mixed fruits orchards that support 98 households along with 18 fruits and nuts focus villages comprising 365 households.

- ✓ The department continued with a number of interventions to improve mandarin farming as citrus mandarin still is one of the highest income earning horticultural produce for Bhutanese. Around 4,360 trees in 26 locations were brought under improved canopy and orchard management approaches which also saw a total of 515 farmers being trained on improved orchard management practices.

- ✓ Subsequent to the government's approval of the National Organic Flagship Program in 2019, a series of activities have been launched. In this reporting period, 24 groups and individual farms comprising 505 households with a total area of 2,410.32 acres have registered with the National Organic Program (NoP), and a total of 2,230.55 acres of land operated by 234 households stand as area under certified organic production.

- ✓ As part of its mandate to ensure safety and quality of farm machines and implements, the Agriculture Machinery Centre (AMC) in collaboration with the Bhutan Standards Bureau (BSB) tested and certified a number of farm machinery including 6 mini power tillers. These certifications now constitute an integral part of formal procedures for availing credit services and subsidies by private entrepreneurs whilst operating their firms.

- ✓ Results from four major studies conducted by the National Plant Protection Center (NPPC) to evaluate the inhibitory effect eight isolates of *Trichoderma sp.* on four different isolates of *P. capsici* since 2017 show that all *Trichoderma sp.* isolates exhibit inhibition of more than 75% on all four isolates of *P. capsici*.This holds huge prospects for sustainable bio-control of fungal diseases that affect chili farming.

- ✓ To help value-add and diversify farm products, the National Post Harvest Centre (NPHC) in this reporting year alone developed 46 different food-processed products. These include bread, cake, candy, chips, chutney, cookies, corn starch and syrup, flakes, herbal drink, jam, muffin, noodles, papad, paste, pickle, soup, syrup, tea, and wine across four categories of crops.

- ✓ Sales volume of farm inputs (seeds) saw an increase as a direct result of the department's mass vegetable production drive initiated as part of the nation's response to Covid-19 pandemic. The National Seed Center (NSC)'s gross revenue for 2019-20 stood at Nu.

172,728,856.85 from the sale of a total of 616.27 MT seeds of vegetable, cereals, oilseeds and seed potatoes.

- ✓ The School Agriculture Program (SAP) presently supports 344 schools. For the reporting year, these schools produced a total of 7, 96,170 eggs and 85.17MT of pork. 300 vegetable demo gardens in these schools also produced 103 MT of fresh green vegetables and potatoes. Schools that ran poultry programs alone contributed to the school SAP revenue of Nu. 9.890 Million.

- ✓ The DoA assisted in the detailed survey and design of about 50 farm road bridges as well as centrally executed the construction of around 68 km length of irrigation system benefiting over 1,200 households spanning a command area around 2,575 acres.

- ✓ The National Soil Service Centre (NSSC) successfully brought around 235 acres of land under several sustainable land management and stabilization interventions. Additionally, about 140 acres of fallow land have been developed and brought into cultivation for laid-off employees as well as groups that included youths as part of the many measures initiated to provide economic relief to affected groups in the wake of the Covid-19 pandemic. The NSSC also analyzed some 7,094 soil, plant and water samples for a range of clients.

- ✓ Several publications were brought out in the reporting period that include seed breeders' manual, technical brochure on potato crop management, herb growers' manual, handbook on sustainable harvesting of endangered medicinal and aromatic plants, fall army worm identification and management guide, and Sunrice herbicide technical brochure, among others.

- ✓ The Department launched the third volume of the Bhutanese Journal of Agriculture (BJA) to help promote a vibrant culture of research and scientific communication amongst its employees.

1 RESEARCH HIGHLIGHTS

1.1 Field Crops

1.1.1 Rice

The reporting year saw the start of a series of research into rice as well as continuation of on-going trials across the four Agriculture Research and Development Centers (ARDCs). Some of the highlights include:

Evaluation Trials

221 new rice lines are being evaluated as part of the preliminary assessment for selection of elite breeding lines under a range of irrigated rice environments. 50 lines from the lot have advanced into observation nursery. These lines are all introduced from the International Rice Research Institute (IRRI), Philippines.

ARDC-Bajo as the coordinating centre for field crops research also has a number of rice varieties at several stages of evaluation, viz. 9 varieties at advance evaluation, 14 varieties at initial evaluation and 13 varieties at observation nursery stages. These trials are aimed at identifying suitable varieties with high yield potential, medium height, optimum maturity and resistance to pest and diseases for mid-altitude rice growing areas. Four promising upland rice varieties are also being evaluated in collaboration with Wangdue Dzongkhag.

Phenotypic Characterization of Traditional Rice Varieties

The department completed phenotypic characterization of 72 accessions of local rice varieties. These were conducted on-station at ARDC-Bajo and ARDC Samtenling in collaboration with the National Biodiversity Centre (NBC).

Production Evaluation Trials

Production evaluation trials (PETs) are being conducted on different rice varieties that are both released as well as those in the pipeline for potential release. These trials evaluate performance on various parameters. In this reporting year, a total of eight rice varieties (4 improved, 3 pipeline and 1 traditional varieties) were evaluated as follows.

Table 1 Production evaluation trial of different varieties on agronomic traits

Variety	Plant Height (cm)	Tiller No	1000 Grain Weight (gm)	Yield (t/acre)
Chandanath-1	95.93	8.40	0.07	1.97
Janam	129.43	13.40	0.07	1.50
Sticky Rice	117.30	7.47	0.08	2.09

Y/PK-Y/B-20	112.47	9.47	0.09	2.13
YusirayKaap 2	111.07	10.07	0.08	1.76
YusirayKaap 3	90.87	6.40	0.10	1.92
YusirayKathamatha	98.90	11.73	0.08	2.25
YusirayMaap 1	108.53	9.67	0.10	2.02

High Altitude Rice Research

Eight popular and released high altitude rice varieties were selected to assess and establish agronomic parameters that could serve as a baseline for future germplasm selection for warm temperate or high altitude rice agro-ecology. The trial collected data on traits like plant height, days to 50% flowering, number of tillers per hill, 1000- grain weight, days to maturity and grain yield per plot (5.04 m^2) as indicated in Table 2.

Table 2 Agronomic traits of different rice varieties

Variety	Plant Height (cm)	Days to 50% flowering	Tiller No	1000 Grain Weight (gm)	Days to Maturity	Yield t/acre
Jakar Ray Naab	104.30	70.67	14.33	19.17	115.67	2.60
Janam	139.63	70.33	13.47	16.39	120.00	2.28
KhangmaMaap	119.10	76.00	12.07	23.33	127.10	2.63
Yusiray Kaap-2	119.87	80.67	10.87	20.27	121.00	2.51
Yusiray Kaap-3	103.73	90.67	10.20	22.22	147.00	2.59
YusirayKathramathra	107.00	91.00	13.00	22.50	145.60	3.10
Yusiray Maap-1	120.20	85.67	12.47	24.73	135.00	2.95
Yusiray Maap-2	111.17	80.00	9.60	20.27	130.00	2.64

Rehabilitation of Popular Traditional High Altitude Rice

Dumbja is popular Bhutanese traditional high altitude rice variety cultivated in warm temperate rice agro-ecology. It is a speciality rice variety known for its aroma. Farmers use this variety to prepare bitten rice (*Sip).* Dumbja is the only traditional variety that is found to be cultivated by the farmers even to this day. Over time, farmers and consumers alike have observed deterioration in its quality traits. Communities have called for research intervention into rehabilitating the variety's superior characters.

Accordingly, 10 accessions of Dumbja were collected from different farmers of Dungna village (Chhukha) and assessed with Yusiray Kaap – 3 as standard check. The research also involved farmer custodians with adequate knowledge on Dumbja who were engaged in participatory assessment of lines with traits closest to the traditional variety. The study will be repeated for another year.

Figure 1 Dumbja rehabilitation trial plots and farmers assessing traits

Research into Organic Weed Management

A 3-year research into organic weed management in rice was initiated by ARDC-OA Yusipang in collaboration with JICA JPP. The research which spanned over three growing seasons (2017 – 2019) at observation plots in Tendrelthang (Thimphu), Paro, Chimipang and Bajo looked into establishing methods of organic rice cultivation without resorting to use of herbicides to control Shochum (*Potamogeton distinctus).* The methods involved puddling the field thrice before transplanting at 15 and 10 days interval after the first puddling. Defatted soybeans (soybean residue) were broadcast soon after transplanting to help prevent root rot as well as a rich source of N. Rice varieties Sasanishiki (Japanese) and Khangma Maap were used in the study. Weeds pressure was found to be largely reduced in the paddy field, possibly due to the impact of butyric acid and lactic acid fermentation in weeds promoted by puddling.

1.1.2 Maize

Release of Heat Tolerant Hybrid Maize (HTMA)

A total of 13 trials consisting 452 HTMA hybrids that were evaluated across the country as nationally coordinated trials over four years has resulted in the release of HTMA hybrid ZH111755 during the 22nd Meeting of the Variety Release Committee (VRC) of the ministry convened on 28 May 2020. The variety is being released as *Wengkhar HM-1*, and it is hoped that this development will contribute significantly in the department's efforts towards ensuring food security, improving nutrition and reducing poverty through increased maize production, and in improving income generating opportunities at the household and community levels.

Figure 2 HTMA Hybrid ZH111755 released as Wengkhar HM-1 (L) & HTMA assessment through PVS (R)

Evaluation of Climate Resilient Hybrid Maize Lines

Following the successful completion of the five-year (2014-18) HTMA maize hybrid evaluation program, the second phase began last year (2019) with the introduction of 45 lines of climate resilient hybrid maize for evaluation by the National Maize Program. The evaluation that was carried out in seven sites in the first year included participatory varietal selection (PVS) by farmers too.

1.1.3 Quinoa

Quinoa (*Chenopodium quinoa* Wild) research and development marked five years since its introduction into the country in 2015. It has now spread into all 20 dzongkhag covering all agro-ecological zones over an estimated area of about 600 acres in 2018-2019 alone. The DoA aims to upscale quinoa cultivation to enhance household food and nutritional security as well as diversify farmers' cropping systems to adapt this versatile climate resilient crop. The consolidated total 12th FYP target for quinoa is 630 acres with an expected production of 310.50 MT.

Production Observation Trial

The DoA completed the production observation trials started at ARDC- Yusipang and later expanded to ARDC-Samtenling (Sarpang) to assess the feasibility of Quinoa cultivation after rice harvest in wet-subtropical zone. Studies into assessing the most suitable sowing time for second crop of Quinoa after potato harvest in high altitude areas of Haa and Paro is also complete and technical recommendations are expected to be out soon including a journal paper.

Enhancing Genetic Base through Multi-Environmental Trials (MET)

The Department of Agriculture established formal linkage with the International Center for Biosaline Agriculture (ICBA) in Dubai as part of its effort to enhance genetic bases

of Quinoa germplasm. The ICBA has generously supplied 20 new Quinoa germplasm which are currently under trial. The department is also expected to receive 186 new entries of Quinoa germplasm for evaluation.

Knowledge and information Management

Building on the extensive experiences gained over the years on Quinoa production, and as an integral technical components requisite to putting in standards in place, the Quinoa Program put together a technical manual on Quinoa seeds production, which was duly endorsed by the department. The publication is expected to be out soon.

1.1.4 Legumes & Other cereals

Chickpea and Soybean Performance Evaluation

Studies are underway on evaluating two new lines of chickpea - JG 14 (ICCV 92944) and NBeG 3 - introduced from the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) India. The study expects to establish data on adaptability and performance in terms of yield, and pest/disease resistance of these elite cultivars. Similarly, the department is in its second year of evaluating eight soybean varieties for their suitability for high altitude dry land cultivation.

Lentils Research

Assessment of different tillage practices in lentils for southern region indicate that better grain yield can be obtained from line sowing after tillage under wetland conditions as compared to relay cropping with paddy using broadcast methods. However, farmers are still recommended to opt for relay sowing or broadcast sowing in wetland if faced with acute labour shortage.

Seed Purification of Grain Legumes

The department initiated seed purification for mung beans as important aspects of seeds production. The program which is slated to continue every year is aimed at providing pure and quality seeds to resource poor and rural farming communities. The program also involved capacity building of 100 farmers in maintenance of purity and quality of improved and traditional varieties, as well as in sharing associated traditional knowledge.

Comparative Studies into Promising Wheat Varieties

Comparative study on two promising wheat varieties BHU 35 and Swadagiri was carried out at ARDC-Sametenling (Sarpang) to assess their yield potential and agronomic traits. The variety Gumasoka was used as check. Statistical analyses showed no significant difference in plant heights. However, significant difference in number of spikelet’s and ear lengths were observed amongst the varieties as well significant difference in yield per plot and 1000-grain weight. The variety Swadagiri outperformed

the others in terms of yield (1.5 MT/ha), and also demonstrated acceptable agronomic traits.

Table 3 Agronomic performance of compared wheat varieties

Varieties	Plant height (cm)	Ear length (cm)	No. of spikelet's	1000 grain weight	Yield harvest (t/ha)
BHU 35	84.82	8.46 b	15.60 b	44.72 b	0.441 b
Swadagiri	81.54	10.32 a	19.36 a	61.54 a	0.344 b
Gumasoka	86.58	7.88 b	15.92 b	51.66 ab	0.589 a
CV (%)	4.82	10.05	8.76	13.76	14.71
P-value	*0.1997*	*0.0063*	*0.007*	*0.0187*	*0.0014*

Participatory Evaluation Trial (PET) of Bio-fortified Wheat Lines

Bio-fortification increases the bio-availability and concentration of nutrients in crops. Bio-fortification, either through conventional plant breeding or recombinant DNA technology is increasingly seen as an emerging alternative to addressing micronutrient deficiencies in developing world. The International Centre for Wheat and Maize (CIMMYT) has developed a number of bio-fortified wheat lines, and Bhutan being part of global wheat network received 50 such entries. There were evaluated for adaptability and performance followed by selection 6 best performing lines which were then subjected to participatory evaluation trial (PET). Although scheduled participatory evaluation could not be conducted due to Covid-19 pandemic, standard crop cut data were collected as follows.

Table 4 Agronomic performance of 6 best performing bio-fortified wheat lines

Sl	Treatments	Days to Heading	Days to Maturity	Plant height (cm)	Disease score (0-5)	Yield (ton/ha)
1	BF 450	93	145	88	0	2.72
2	BF 422	92	138	90	0	2.74
3	BF 411	96	135	89	0	2.48
4	BF 447	95	140	90	0	2.70
5	BF 412	90	140	91	0	3.33
6	BF 415	92	145	92	0	1.80
7	Bumthang ka drukchu (local check)	94	155	94	0	2.10

Wheat Breeder Seed Maintenance

In order to augment the National Seed Centre's production of wheat seeds, the department also produced seeds of various promising wheat lines for multiplication and

on-farm testing as well as seeds of released wheat varieties for maintenance lines (see Table 5).

Table 5 Wheat seed production by ARDCs (2019-20)

Line/variety	Quantity (kg)
Bumthangkaa Drukchu	2050
Bajosokha kaa	150
Gumasokha kaa	200
Total	**2400**

Characterization of Local Landraces of Foxtail Millets

Characterization of different finger millet varieties from Lhop communities was carried out on-station in ARDC-Samtenling. Thirteen different landraces were collected, and subsequent characterizations were undertaken following standard procedures prescribed by the International Union for the Protection of New Varieties of Plants (UPOV) for various morphological and agronomic parameters (See Table 6).

Table 6 Morphological and agronomic parameters of foxtail millet landraces

Variety	Plant height (cm)	Finger Nos	Finer length (cm)	Flag leaf length (cm)	Plot yield (kg)	Yield t/ha
1. Lung Ramtay (Taba, Dorokha)	92.10	7.10	5.50	45.00	0.33	0.80
2. Jatsho	91.60	6.80	4.40	49.20	0.32	0.80
3. Seri (1000masl)	89.80	7.60	3.00	46.40	0.26	0.60
4. Ek lung	100.20	5.40	8.40	46.00	0.35	0.87
5. Lung Lung (Sengden)	101.60	9.20	6.00	48.00	0.36	0.88
6. Sarja (Dorokha)	101.00	6.20	6.20	51.40	0.32	0.80
7. Gaasheng	79.00	4.80	4.80	47.80	0.39	0.97
8. Sari (900 masl)	79.20	6.00	5.00	41.80	0.38	0.95
9. Chakdho (Aggchag)	78.80	4.80	5.00	40.60	0.34	0.85
10. Juong Jha	102.00	7.00	7.60	55.40	0.33	0.80
11. IE4414	95.00	7.20	3.80	41.60	0.43	1.07
12. IE 4425	92.00	6.70	5.40	45.20	0.42	1.05
13. SamtenlingMemja 1	93.80	8.00	4.60	44.60	0.51	1.27

1.2 Horticultural Crops

1.2.1 Vegetables

Release of High Yielding Varieties

The department approved the release of two high yielding bean varieties. Following the successful performance evaluation for two consecutive years at ARDC-Samtenling, a

variety of Japanese Dwarf bean (*Phaseolus vulgaris* L.) was released as *Samtenling Semchu-1* while variety "prime green" was released as *Bajo Semchumkaap* after 3-years of consecutive evaluation showed significantly higher yield as against check variety Grey Pole.

Evaluation of Vegetable Varieties

The reporting year 2019-20 saw a significant number of vegetable varieties being evaluated for performance across the four ARDCs as summarized below:

- Ten different vegetables species on their nutrient content study and nine different vegetables for their performance at ARDC Bajo.
- Evaluation of Cosmic hybrid tomato for performance under protected cultivation at ARDC Yusipang in comparison to local check varieties Ratan and Roma.
- Evaluation of four tomato, three chilli, two egg plant, four cabbage, two cauliflower, four cucumber, three kale, two yard long beans and one radish varieties in the east.
- Fast track evaluation of tomato variety Garv, cauliflower hybrid Early Aghani and Poosi at ARDC Samtelling. Preliminary results show that the average yield/acre of Candid charm as 9.75 MT, KSB-12-182 as 9.5 MT and Snow Mystique as 6.61MT.

Characterization of Traditional Chilli and Bean Varieties

ARDCs Wengkhar, Yusipang and Samteling initiated collection of more than 25 chilli entries from across the country for morphological characterization using IPGRI descriptors. 45 accessions of common beans were collected from southern Bhutan and are being evaluated as per IPGRI 1981 descriptors. Additionally, beans accessions sourced from the National Biodiversity Centre (NBC) are being assessed for their growth habits and biology at ARDC-Yusipang.

1.2.2 Potato

The department's National Potato Program's thrusts areas include enhancing potato production through off-season farming, technology transfer (demonstration of new varieties), farmers' capacity development and evaluation of potato germplasm for variety development. These activities also attempt to address the stagnation in yield due to degeneration of seed and varieties. The program targets to release four new high-yielding, late-blight resistant and climate-resilient varieties in the 12th FYP.

Summary of programs and initiatives for the reporting year exclusive of on-going ones initiated in preceding years include:

Multi-location Varietal Trials

On-station multi-location trial was conducted on 7 potato clones (395436.8, 399004.19, 306518.1, 394611.112, 399073.18, 399062.119 and 397196.3) with Desiree as check variety in Bumthang and Khangma. It also includes on-farm trials in Thragom, Yongphula, Mertshem, and Dekiling villages followed by Participatory Varietal Selection (PVS) at harvest where yield and tubers were segregated and seeds and non-commercial sizes were recorded. Trials are scheduled to continue.

Knowledge and Information Management

Brochures on potato crop management have been developed to assist extension, researchers and growers in all aspects of potato farming. The program also completed a potato seeds breeders' manual as part of the department's breeder seeds manual for all major crops.

All in all, research highlights for the program can be summarized as hereunder.

Table 7 Summary research achievement (2019-20) for the Potato Program

Success indicators	Units	Target	Achieve-ment	Achievement (%)	Remarks
Multiplication of bio-fortified tetraploid clones into micro-tubers	No	50	50	100	In collaboration with NSC
New varieties demonstrated and promoted	kg	2000	3875	194	21 gewogs in 13 Dzongkhags
New improved potato clones evaluated/multiplied for research	No	45	46	102	26 evaluated & 20 climate resilient clones multiplied in Khangma, Bumthang, Phobjikha & Yusipnag
Demonstration on new clones through germplasm maintenance	Date	Sept 2019	Sept 2019	100	Two demo-plots (conventional & organic)
Farmers capacity developed	No	500	589	117.8	Chukha, Mongar, Trashigang, Wangdue & Trongsa

1.2.3 Fruits and Nuts

Release of Fruits Varieties

The department released a series of fruit varieties in a culmination of several years of assessment. Local pineapple accession PV1 and PV3 were released as *Samtenling Kongtsey 1 and 2* based on their significant performance against other accessions in terms of their physical and physico-chemical characteristics.

The department also released a new plum variety *Yusi-prune 1*. Yusi-prune 1 has immense potential in commercial horticulture as it is one of the most popular of prune-plums – those plums grown principally for drying and are of mostly European origin. It is a late-maturing, cold-hardy and easy to grow variety. It matures in Sept – Oct when other plums are out of season, and can be eaten fresh, canned, dried, preserved or processed into other products. Its original germplasm was introduced at ARDC-Yusipang back in 1994.

Banana variety Grand Naine was released as *Samtenling Ngangla 1* follwing years of on-station evaluation at ARDC-Samtenling. An important variety from Israel, Grand Naine is known for its tolerance to abiotic stresses and good quality bunches. The fruit develops attractive uniform yellow colour with better keeping quality and shelf life. The variety can also be easily mass multiplied through tissue culture.

Wine Grapes Research

Subsequent to the approval granted by the Ministry of Agriculture and Forests (MoAF), the Department of Agriculture (DoA) and Ser Bhum Brewery (Ser Bhum), now incorporated as Fine Bhutan Wine Pvt Limited initiated a joint research trial on wine grape varieties for possible establishment of wine industry in Bhutan. Nine wine grape varieties were imported from the US and introduced for assessment at four sites in ARDC-Bajo, Wengkhar, Yusipang and the National Seeds Centre (NSC). Experts from the US along with their promoters took part in the initial establishment of the trial that involved around 3,200 grafted wine grape seedlings. Preliminary findings on their performance are expected in the next reporting year.

Fruit Propagation through Tissue Culture & Germination Studies

Lack of kiwi and persimmon rootstocks poses a challenge in the production of grafted seedlings. Thus, the need to study alternative methods of propagation. ARDC-Wengkhar initiated Kiwi and persimmon propagation through tissue culture using 7 different media. A total of 48 numbers of kiwi and 24 numbers of persimmon culture are being grown in the growth chamber.

To overcome issues with recalcitrant seeds in kiwi fruits, germination rate were assessed on four different media using two separate duration of stratification at 1500 ppm Gibberellic acid (GA3). Among the treatments, Biochar with Gibberellic acid application gave the best result of 63% followed by coco peat with Gibberellic and Biochar. Further confirmatory evaluation is underway.

1.2.4 Citrus

Clean Planting Material Production

With most mother plants in the country suspected to be infected with HLB and other diseases like CTV the department has provided added impetus on production of clean disease-free mother stocks from infected but superior lines. Shoot tip grafting offers a

possible way out. ARDC-Wengkhar has initiated shoot-tip grafting research and to date the centre has managed to shoot-tip graft 26 plants comprising seven citrus varieties which were thereafter approach-grafted onto healthy rootstocks in February 2020. Mexican limes grafted onto C-35 rootstocks are being raised as indicator plants, which will be used for testing the shoot-tip graft originated plants for HLB.

On-Farm Evaluation of Citrus Varieties

A series of on-farm evaluation trials are being conducted across the country on a range of improved citrus varieties.

a) New varieties Afourer, Parson Brown, Ryan and Benyendra Valencia are being assessed by ARDC-Samtenling at 200 masl with Taraku (Wenkhar Tshelu Ngarm) as check.
b) An acre of demonstration cum management trial at Punakha Khamsum Yully Chorten has been established consisting of the varieties Clementine, Taraku, Otsu, Otha ponkan, Teishu ponkan and Bearss lime.
c) Variety trial on five public access varieties (PAVs) imported from Australia is underway in Lochina (1,000 masl) and Pachu (500 masl) in Chhukha. The varieties include Tarocco Ippolito, Cant Star Ruby, Parson Brown, Caffin, and Afourer with Dorokha Local as check.
d) ARDC-Wengkhar is evaluating seven promising citrus varieties for processing at three different altitude ranges (730 – 1,488 masl) in Saling Gewog (Mongar).

1.2.5 Mushroom

A series of research on mushroom is being conducted at the National Mushroom Centre (NMC) in an effort to enhance mushroom production and diversify available options for growers. A gist of the studies currently on-going and those in completions are as follows:

Mushroom Varietal Evaluation Studies

Studies into evaluating Oyster mushroom strains were initiated last July. Preliminary results show the variety Oyster Nepal has the highest biological efficiency (BE) at 84.28% followed by variety HOY (86.88%). Eventually best performing cultivars for summer crop will be selected.

Studies on Fruiting Ability of Hybridized Shiitake Strains

Fruiting abilities were compared amongst seven new shiitake mushroom strains. These strains were developed by the NMC through hybridization in 2018 with technical support from JICA Partnership Program. Strains B465 (JBS) F and B465 showed the highest average production at 88.03 gm and 82.39 gm respectively. The research is also expected to provide insights into their mycelia colonization rate, fruiting ability and disease tolerance.

1.2.6 MAPS

Evaluation of Water Wasabi Water Wasabi {*Eutrema japonicum* (Miq.) Koidz} research was initiated in collaboration with Mac & Me. Co. Ltd., based in Bangkok, Thailand and ARDC-Yusipang at Tendrelgang Community Forest, in Yusipang, Thimphu. The research aims to evaluate the performance of Wasabi (variety Ozawa) in order to assess the potential for introduction of Wasabi cultivation in Bhutan to help generate additional farmer income.

Figure 3 Water wasabi research at Tendrelthang, Yusipang

Preliminary findings indicate that water wasabi can be grown successfully in Bhutan. Initial observation on plant height, flowering time, flower numbers, leaf numbers, and leaf diameters were made which indicate that the plant attains a maximum height of 38.02 cm in June with mean plant height of 25.43 cm. Maximum flowers were recorded in April. The study is expected to recommend suitable altitude and right planting season for optimum Wasabi cultivation in Bhutan.

Evaluation of Different Organic Manure Effect on Manu (Inula recemosa) and Turmeric Yields

Assessment into the effect of different types of organic manures on the yield and agronomic traits of the medicinal plant Manu and Turmeric (*Curcuma longa*) are being conducted at ARDC-Yusipang, Thimphu. Manu is an important medicinal plant used significantly in traditional medicine formulation, while turmeric is an important spice which is also used widely as a dye, drug and in cosmetic applications. The study expects to provide insights into potential in turmeric cultivation at high altitudes.

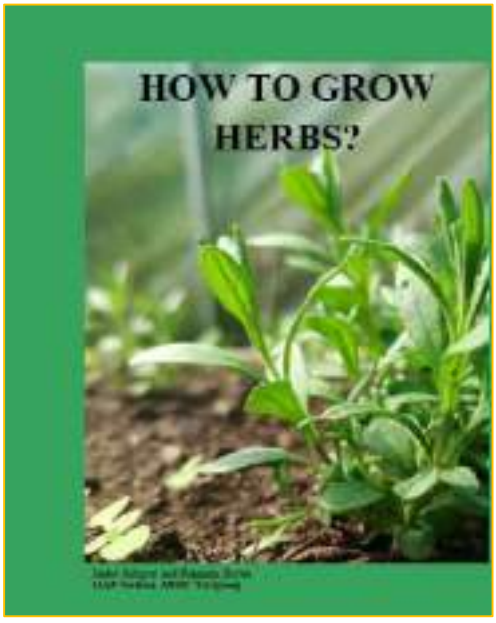
Herb Garden Development

ARDC-Yusipang houses a repository or live herbarium of important medicinal plant species collected from within the country as well as species introduced from outside. The garden serves as a demo site for students, entrepreneurs and MAP enthusiasts besides doubling up as an on-station observation trial and source of mother plants for

possible multiplication of species of interest. The reporting year saw a major re-haul of the herbarium with the entire set re-designed engaging the services of a private architect firm.

Knowledge & Information Management

The Medicinal, Aromatic Plants and Spices Program (MAPS) took out two handbooks: Sustainable Harvesting Guidelines for Endangered MAP Species in Bhutan and How to Grow Herbs? The handbook on harvesting provides general guides for sustainable harvesting of selected and prioritized medicinal plant species whereas the herb growing guide contains basic production practices of 16 culinary herbs.



1.2.7 Plantation Crops

Release of Tea Accessions and Characterization Coffee Varieties

The department released two accessions of tea SIT and PNW as *Sam Ja 1* and *Sam Ja 2* respectively based on their bio-chemical content, crop suitability and processing potential. This was based on the morpho-biochemical evaluation conducted successfully on four accessions: AST (Assam Tea), SIT (Samcholing Indigenous Tea), RSK (Republic of South Korea) and PNW (Prince Namgyal Wangchuck).

Characterization of three coffee (*Coffea spp.)* accessions - ACOF (Arabica coffee), RCOF (Robusta coffee) and TCOF (Thai coffee) at ARDC-Samtenling indicate that the accessions ACOF and RCOF performed the best. They are being further evaluated for potential release in the coming year.

Figure 4 Sam Ja 1 (left) and Sam Ja 2 (right)

Green Tea Product Diversification

ARDC-Samtenling assessed and developed a processing flow chart for green tea and other crops like moringa, guava and sour-sop. These were put together after conducting on-farm assessment as well as in keeping with prescribed international standards for processing each of these crops. This is expected to add value to these plantation crops and thereby provide impetus to their production.

1.2.8 Floriculture

Promotion of Native Ornamentals

With growing popularity of floriculture and increasing demand for ornamental plants, the department has initiated promotion of sustainable use of native plants in landscaping. This is expected to not only help sustain native plants but also in providing alternatives to ornamental sources for landscaping and beautification programs. Supported by BTFEC, the floriculture program collected around 200

numbers of 15 different native ornamental plant species from various locations in Thimphu, Paro and Haa for germplasm maintenance and onward propagation.

1.3 Organic

Permanent Research and Organic Demonstration Plot

Permanent research and demonstration plots were established across the four ARDCs. These will serve as sites for research and demonstrations on organic technologies. These include vermin-composting, vermin-wash production, kitchen waste composting, nutritional garden, bio-digester, water management technology and low cost poly-tunnel for nursery raising amongst others.

Figure 5 Organic vermin-wash and vegetable production demonstrations

2 DEVELOPMENT HIGHLIGHTS

2.1 Field Crops

2.1.1 Rice

Drought Tolerant Upland and Spring Paddy Intensification

In continuation of the initiatives from the previous years in improving farming households' resilience against climate change impacts, the department directly supported the cultivation of around 116 acres of upland paddy. This is an important intervention aimed at providing opportunities for households beyond 1,800 masl to diversify maize cropping system with rice. Drought tolerant upland paddy varieties come as one of the key options to enhance rice productivity and ensure rural self-sufficiency. An estimated production of 139 MT paddy is expected from target villages

in 5 eastern dzongkhags of Lhuentse, Mongar, Trashigang, Pemagatshel and Samdrup Jongkhar. The department also supported in bringing 73.89 acres under spring paddy cultivation.

Maintenance & Basic Seeds Production

The DoA at its research centre in Yusipang also produced around 2 MT of basic seeds of eight released rice varieties as part of its regular maintenance and seed purification program. In addition to supporting the National Seeds Centre (NSC), these seeds were also used in promotion programs in Paro and Gasa dzongkhags.

2.1.2 Maize

Community Seed Production and Seed Replacement

As an important cereal crop, maize seeds continue to feature as a priority for farmers. Quality seeds play a crucial role and therefore the need to support farmers in producing and maintaining quality seeds. In the last season, six community based seed production (CBSP) groups in eastern Bhutan produced over 56.64MT of quality maize seeds, out of which the National Seed Centre (NSC) procured about 50 MT. At the given seed rate of 15kg/acre, the production would cover an area of 3,333 acres, directly contributing towards seed replacement across the country.

Hybrid Maize Intensification

In continuation to the Spring Maize Program first initiated in 2015 which brought about significant progress in intensifying cropping systems, directly benefiting hundreds of households in the east, a total a total of 14 MT hybrid P3502 seeds was procured and grown in seven districts covering 913 acres in the 2019-20 reporting year. Farmers have shown increased interest in this hybrid technology. The program involved use of 9.66 MT of hybrid maize (P3377) seeds covering a total of 670 acres in six eastern Dzongkhags (see Table 8).

Table 8 Hybrid maize intensification program in selected dzongkhags

Sl	Dzongkhags	Seed Qty (MT)	Area (AC)
1	Dagana	3.68	246
2	Mongar	3.16	211
3	Pemagatsel	3.49	233
4	Gelephu	0.50	33
5	Tashigang	2.04	136
6	Tashiyangtse	0.32	21
7	Samdrup Jongkhar	0.50	33
8	ARDCs	0.31	
	TOTAL	**14.00**	**913**

2.1.3 Quinoa

Quinoa Promotion and Basic Seeds Production

Following its introduction in 2015, quinoa has been aggressively promoted in all 20 dzongkhags. Regional ARDCs and dzongkhags have successfully coordinated the production of 76.96 MT of Quinoa in FY 2019-20 covering 381 households over 120 acres. The commodity is now mainstreamed into the dzongkhag 12th FYP targets where it is now being promoted, including in Farm Machinery Corporation Limited (FMCL) farms and through the Land Use Certificate (LUC) user groups.

In fulfilling the usual demand for Quinoa seeds, ARDC Yusipang continues to provide support not only in terms of technical backstopping but also in production and supply of seeds. The past reporting year saw the Quinoa Program producing 1,100 kgs of Quinoa basic seeds as against its target of 1,000 kg. These were supplied to ARDCs as well as the NSC who also exported some portion to Armenia (of the variety Amarilla Marangani).

2.1.4 Legumes & Other Cereals

Lentils and Grain Legumes Promotion

As part of the research outreach program (RoP) ARDC-Samtenling promoted lentils, rajma and mung beans production across seven dzongkhags of Dagana, Samtse, Sarpang, S/Jongkhar, Tsirang, Trongsa and Zhemgang. In total the initiative cultivated over 37 acres with a production of 8.5 MT of beans and lentils. Additionally, ARDC-Wengkhar, as part of its legume intensification program with financial support of CARLEP promoted the production of 1.85 MT of Rajma beans in Lhuentse and Mongar on 14 acres.

Sustainable Intensification of High Yielding Wheat Variety

The Department of Agriculture released two wheat varieties (Bajosoka-ka and Gumasoka-ka) back in 2015 to address various constraints in wheat cultivation in eastern Bhutan. However, farmers in the east continue to grow poor yielding local varieties. In response to this, the program on sustainable intensification and commercialization of wheat looked at promoting these improved cultivars to help increase productivity and production. These programs focused on potential wheat growing areas of eastern region with inherent issues of poor soil fertility and higher incidence of poverty. The initiative distributed around 3.8 MT of wheat variety Gumasoka- ka amongst 12 geogs in four districts of Lhuentse, Mongar, Tashiyangtse and Samdrupjongkhar covering 97.21 acres. Benefiting 173 households, the program which is supported by CARLEP-IFAD funding is expected to produce around 59 MT of wheat.

2.2 Horticultural Crops

2.2.1 Vegetables

Promotion of Commercial Vegetable Cultivation

In support of the DoA's efforts into enhancing commercial vegetable cultivation, ARDCs Wengkhar promoted cultivation of 15 vegetable crops on 102.1 acres in five dzongkhags of Bumthang, Lhuentse, Mongar, Trashigang and Trashiyangtse benefiting 154 households and institutions. The centre also advocated cultivation of bulb onion after rice harvest in more than 37 acres of land in 5 eastern dzongkhags involving 187 households with an expected production of over 290 MT. In addition to mass vegetable production on-station, ARDC-Bajo produced around 323 kg of vegetable seeds, sufficient to cover over 236 acres of cultivation.

Winter Chilli and Vegetable Commercialization

The DoA's initiative on winter chilli production to help minimize imports through commercialization has come a long way. Though unhindered supplies to major markets in the winter is still a challenge, three consecutive years of winter chilli commercialization program (2017-2019) saw tremendous increase in both area and production. Overall cultivation expanded from 272 acres in 2017 to 799 acres in 2019. The department has now limited its support to distribution of hybrid seeds and respective dzongkhags are expected to continue the initiative in consultation with growers on their own or through cost-sharing approaches. ARDCs also supplied more than 10,000 nos. of hybrid chilli seedlings to six households in Sampheling (Chhukha), while ARDC-Bajo produced around 158 kgs of winter vegetable seeds to be distributed to the farmers for commercial production in the coming season.

Table 9 Winter chili production, acreage and income (June 2019- April 20)

Dzongkhag	No. of HHs	Area (acre)	Actual Production (Kg)	Sale Volume (Kg)	Avg. Price (Nu)	Amount Earned (Nu.)
Chukha	61	15	5,575	5,575	142	790,256
Dagana	199	59	64,293	58,739	148	8,710,080
Pema Gatshel	101	16	6,726	5,764	209	1,206,117
Samtse	1344	118	96,900	64,550	180	11,619,000
Sarpang	408	121	103,211	76,384	174	13,263,040
Tsirang	221	34	34,120	25,903	138	3,567,443
Wangduephodrang	2045	434	1,452,220	1,016,554	40	40,662,166
Zhemgang	11	1.4	1,462	1,462	150	219,300
Grand Total	**4390**	**799**	**1,764,507**	**1,254,931**	**148**	**80,037,402**

Promotion of Protected Vegetable Cultivation

The department continued its support in promoting protected technologies like green houses along with water use efficient technologies (micro irrigation system) to help increase production during the winter season. The department supported a total set of

52 greenhouses worth around Nu. 1.92 million that included 25 sets of low-cost green house to Merak Gewog (Trashigang) to help dietary diversification through winter vegetable cultivation.

Likewise, the department provided a range of improved irrigation and water storage equipment along with mulch materials to farmers in southern dzongkhags. These are expected to help ease drudgery in intensive weeding operation in vegetable farming and provide relief to farmers during water-scarce winter months (see Table 10).

Table 10 Part of the support provided for protected vegetable cultivation

Dzongkhag	Drip irrigation (set)	Silpaulin plastic (nos)	Plastic Mulch (rolls)
Chukha	16		18
Dagana	64	25	80
Samtse	42	10	60
Pema Gatshel	10		10
Sarpang	70		90
Tsirang	10	25	55
Zhemgang	32		20
TOTAL	**244**	**60**	**333**
Cost/Unit (Nu)	**6550.86**	**5285**	**2615**
Cost Total (Nu)	**1,598,409.84**	**3,17,100**	**8,70,795**
Acreage	**15.25**		

Urban Agriculture Initiative

As part of the many responses to COVID-19 pandemic, the department in collaboration with Thimphu Thromde and Thimphu Dzongkhag initiated the Urban and Peri-urban Agriculture Farming Program in and around Thimphu for furloughed employees that mainly comprised those from the tourism sector. The program with additional fund from the Food and Agriculture Organization (FAO) involved a total of 22 groups comprising 87 members who were provided with land development services, vegetable seeds/seedlings, organic manure, electric fencing and agriculture tools worth Nu.5,07,239.00.

2.2.2 Potato

The Potato Program's key development highlights for 2019-20 include technology transfer through demonstration of new varieties, winter or off-season potato production, seed multiplication of released cultivars, etc., as detailed hereunder.

Table 11 Development highlights for Potato Program (2019-20)

Success indicators	Units	Target	Achieve-ment	Achievement (%)	Remarks
Winter (off-season) potato production – seed support	Kg	8000	8000	100	Sarpang & S/Jongkhar
Promotion of late-blight resistant & nutrient dense potato varieties	Kg	8000	9000	112.5	28 geogs (13 dzongkhags)
Seed multiplication of newly released varieties	MT	6	22.47	374.5	Haa, Paro, Thimphu, Mongar, Bumthang, T/Gang & P/Gatshel

2.2.3 Fruits and Nuts

Some of the primary development highlights for the Fruits & Nuts Program of the Department were:

a) **Demonstration orchards:** 99 mixed fruits demonstration orchards were established with 7,319 seedlings, supporting over 98 households by ARDC-Wengkhar. Additionally, a total of 34,215 seedlings were produced to support farmers with their demonstration orchards by ARDCs – Samtenling, Bajo and Yusipang.

b) **Focussed Village Fruits Promotion:** 18 focus villages for fruits and nuts were established comprising 365 households. These households received around 6,430 numbers of grafted fruits seedlings.

Additionally, ARDCs in total supported 44.5 acres of watermelon cultivation involving 105 households. The initiative is expected to produce around 65 MT of watermelons.

2.2.4 Citrus

As in the previous reporting year, the department implemented a number of programs to support, develop and sustain the citrus industry.

Area-wide Citrus Canopy & Orchard Management and Demo-orchards

In continuation with the preceding years' initiative ARDC-Bajo in coordination with other ARDCs and respective dzongkhags carried out nation-wide citrus canopy management and hands-on training for 7 dzongkhags in 26 locations. A total of 4,360 citrus trees had their canopies managed. Additionally, farmers and extension staff were educated on essential orchard pest and nutrient management practices (see Table 12).

In order to promote farmer adoption of improved and best practices, ARDC-Yusipang started three mandarin orchards – 120 plants each – followed by hands-on training on

canopy management in Bongo and Dungna in Chhukha. An additional 19 orchards were also established in Zumsa comprising a total of 1,520 mandarin seedlings which were jointly supported by the centre and the dzongkhag.

Table 12 Canopy and orchard management initiatives (2019-20)

Dzongkhag	Gewog	Bearing trees	Non-bearing trees	Total trees	Canopy managed trees	Farmer participants	Extension participants	Days	Location
Wangdue	Gasel-Tshowom	609	271	880	185	30	12	1	1
Zhemgang	Pangbang	688	380	1,068	376	49	58	3	2
Pemagatshel	Norbugang	5,978	1,385	7,363	2,338	170	303	10	7
Samdrup Jongkhar	Orong	100	53	153	114	45	20	1	1
	Gomdar	2,000	700	2,700	134	29	40	2	2
Samtse	Dophuchen	200	30	230	30	30	5	1	1
	Dumtey	350	90	440	81	26	5	1	1
Sarpang	Gakidling	252	10	262	199	72	14	3	3
Mongar	Kengkhar	581	570	1,151	903	64	30	2	8
		10,758	**3,489**	**14,247**	**4,360**	**515**	**487**	**24**	**26**

Climate Smart Water Management for Citrus

Smart irrigation approaches were promoted in Mongar and Lhuentse on cost-sharing modalities that covered 2 acres of plantation. Additionally, ARDC-Bajo established climate smart irrigation facilities for citrus orchards benefitting around 224 households in Dagana, Punakha, Wangdue and Zhemgang. These facilities include drip irrigation, water ponds, as well as restoration of irrigation systems over 1,286.5 acres of command area.

Promotion of Kumquat Cultivation

In response to the increasing popularity of Kumquat cultivation, particularly in view of its potential for use in nectar and marmalade preparations, ten Kumquat orchards were established by ARDC Wengkhar grafted materials. These orchards are based in Dedrang and Pekchurung villages (Mongar Gewog) and in Thridangbi (Saling Gewog). ARDC Wengkhar plans to link these growers with Kumquat processor at Thridangbi.

2.2.5 Mushroom

Spawn Production & Supply and Mushroom Production

Contributions made in terms of mushroom development for the financial year include spawn production and supply, supporting rural farmers and commercial growers and capacity building of mushroom cultivators by the National Mushroom Centre supported by ARDCs are detailed in Table 13.

Table 13 Support to mushroom production (2019-20)

No	Activities	Achievements	Remarks
1	***Spawn Production***		
	i. Shiitake	31,474 bottles	Sawdust and grain spawn
	ii. Ganoderma	54 bottles	
	iii. Oyster	12,262 bottles	
	iv. Button mushroom	71 bottles	
	v. Hericium mushroom	55 bottles	
	vi. Nameko mushroom	32 bottles	
2	***Spawn Supply***		
	i. Shittake	13,864 bottles	
	ii. Oyster	7,765 bottles	
	iii. Ganoderma	124 bottles	
3	***Cultivation***		
	i. Shiitake	1,27,873 billets	Growers in 17 dzongkhags (210 households)
	ii. Oyster	13,840 bags	
4	***Backstopping growers***		
	i. Field/farm monitoring	158 farms	Central & western dzongkhags

Capacity Building

Training on wild mushroom management and sustainable harvesting was conducted in Geney at Thimphu and Ura in Bumthang where members from mushroom management groups attended. Internship program for five interns, three from Chimipang Royal Project and two private spawn producers, was also organized in June 2020 at Wangchutaba. These were aimed at imparting basic knowledge and skills on mushroom spawn production to encourage and promote commercial mushroom growing.

Figure 6 : Practical training: Tissue culture (A), Sawdust spawn preparation (B) & Grain spawn preparation (C)

Awareness and Advocacy

The NMC carry out awareness program on wild mushroom poisoning every year before the onset of mushroom season through television, social and print media. With three mushroom poisoning cases reported earlier this May in Dagana, Tsirang and Sarpang resulting in death of a 3-year old child, officials from the NMC and Tsirang Dzongkhag Hospital visited the sites to assess mushrooms and provided awareness to the public and distributed posters on edible and poisonous mushrooms.

Figure 7 Awareness program on mushroom poisoning

The centre also provided lectures to two batches of De-Suup trainees (35th and 36$^{th)}$ in September and November 2019 respectively on aspects of mushroom identification and mushroom poisoning.

Mushroom Festival

The National Mushroom Centre (NMC) attended the Fifth Annual Mushroom Festival, in Geney, Thimphu and Ura Mushroom Festival in August 2019.This is as part of the annual initiative in creating awareness on sustainable harvesting of mushroom and the threat of mushroom poisoning amongst stakeholders, and in an effort to showcase the natural wealth of the locality as well as to promote economic opportunities associated therein.

2.2.6 Plantation Crops

Multiplication of Plantation Crops

ARDC-Samtenling produced more than 6,140 healthy seedlings for establishment of demo-orchards of released varieties as well as for on-farms evaluation of plantation crops across the country. The seedlings were multiplied in keeping with the requirements for ultra-high density orchard set-up.

Table 14 Multiplication of plantation crops seedlings (2019-2020)

Sl	Crops	Seedling No.
1	Arecanut (*Areca catechu)*	3,700
2	Coffee (*Coffea arabica & robusta)*	1,200
3	Tea*(Camellia sinensis var. sinensis & assamica)*	500
4	Cocoa (*Theobroma cacao)*	700
5	Sacha inchi (*Plukenetia volubilis)*	40
	Total seedlings	**6,140**

2.2.7 Floriculture & Amenity Landscaping

Figure 8 Tulips (left) and daffodils (right) at the FALC in Dechenchholing, Thimphu

Production of Assorted Ornamental Plants and Floral Displays

The Floriculture and Amenity Landscaping Centre (FALC) in collaboration with ARDC Bajo and the Royal Project Coordination Office produced over 69,000 numbers of 22 different species of ornamental plants in the fiscal year 2019- 2020. The programme organized flower displays on three important events - birth Anniversaries of His Majesty The King and Her Majesty The Gyaltsuen, and birth of HRH Gyalsey Ugyen Wangchuck. Additionally, over 36,000 flowering plants (17 different species) were produced for the 6th edition of the Royal Bhutan Flower Exhibition. The exhibition which was scheduled in early June 2020, had to be postponed due to Covid-19 pandemic.

Technical Backstopping

The program also provided the technical assistance to a series of initiatives:

a) Training on floriculture and landscaping to Sarpang and Tsirang dzongkhags staffs, including gardeners of dzongkhags and regional offices.

b) Technical support to Haa Dzongkhag Administration in developing the beautification plan for Royal Bhutan Flower Exhibition 2020.

c) Technical support for Chorten Kora landscaping and beautification.

d) Landscaping and beautification at Singye Pelri Palace, Punakha.

Figure 9 Part of flower nursery at FALC, Dechenchholing, for Royal Bhutan Flower Exhibition 2020

2.3 Organic

Subsequent to the government's approval of the National Organic Flagship Program (NoFP) in 2019, a series of activities have been launched to take forward the initiatives of the National Organic Program (NOP). Some of the highlights for the reporting year including regular organic agriculture programs by the NOP are summarized as below:

Area under Organic Management

In the FY 2019-20, total of 24 groups and individual farms comprising 505 households with a total area of 2,410.32 acres have registered with NOP (see Table 15). It includes 2,143.7 acres of community forest registered by the Geney Mushroom management group from Genekha Gewog under Thimphu and other areas under agriculture production. Area under organic agriculture refers to the total organically managed recorded with the National Organic Program, and targeted towards certification through the Local Organic Assurance System (LOAS) for domestic market and Third-Party Certification for export market.

Table 15 Total area under organic management (2019-20)

Sl	Dzongkhag	Gewog	Commodity	No. of HH	Areas (Ac)
1	Paro	Luni	Rice & vegetables	1	7.0
2	Haa	Samar	Buckwheat & vegetables	56	37.2
3	Wangdue	Kazhi	Vegetables	5	15.0
4	Sarpang	Chudzom	Vegetables	164	49.7
		Samtenling	Coffee	3	3.0
5	Thimphu	Genekha	Masutake	126	2143.7
6	Punakha	Goenshari	Edible flowers	5	1.6
		Limbukha	Vegetables	1	5.0
7	Tsirang	Doonlagang	Kiwi	1	3.0
8	Zhemgang	Nangkor	Local quinoa	7	4.0
9	Chhukha	Bjabchho	Vegetables	12	8.0
10	Samdrup Jongkhar	Orong	Ginger	64	32.0
		Dewathang	Ginger	30	13.0
11	Samtse	Phuntshopelri		3	10.1
		Tendu	Vegetables	22	26.0
		Yoeseltse	Vegetables	5	16.0
	Total			**505**	**2,410.3**

Area under Certified Organic Production

A total of 2,230.55 acres of land operated by 234 households has been certified through LOAS in the 2019-20 reporting year, including 2,143.7 acres of community forest land managed households of Geney Mushroom Management Group, Genekha in Thimphu Dzongkhag for collection of Matsutake mushrooms. Seventeen new products produced by nine groups were certified under LOAS (See Table 16).

Table 16 Total area under certified organic management (2019-20)

Sl	Name of Groups/Operator	Dzongkhag	Gewog	HH/ Farmers	Area (Acs)	Certified Crops	Unique Identify No. (UIN)
1	Chimakha Organic Farm	Paro	Luni	1	7.0	Asparagus Apple Rice	18/1802/LOAS/I/17
2	LongpaNobgang Model Organic Village	Haa	Samar	56	37.2	Buckwheat flour	15/1504/LOAS/GP/16
3	Lull Organic Model Village	Wangdue	Kazhi	5	15.0	Garlic Chilli Wheat Potato	29/2908/LOAS/15
4	Gungrig Model Organic Village	Sarpang	Chudzom	36	15.0	Beans	23/2304/LOAS/GP/19

5	Geney Mushroom Management Group	Thimphu	Genekha	126	2,144	Matsutaki	24/2403/LOAS/GP/18
6	Bhur Organic Farm	Sarpang	Samtenling	3	3.0	Coffee	23/2301/LOAS/I/14
7	Drachukha Flowers Group	Punakha	Goenshari	5	1.6	Edible flowers	220/2004/LOAS/GP/12
8	Ashish Horticulture and kiwi nursery	Tsirang	Donglagang	1	3.0	Kiwi	28/2803/LOAS/13
9	Gyaki OrganicFarm	Punakha	Limbukha	1	5.0	French Beans Cauliflower Broccoli Zucchini	20/2007/LOAS/1/20
	Total			**234**	**2230.55**		

Production of Organic Commodities

A total of 1,571.45 MT of selected commodities (quinoa, buckwheat, ginger, turmeric, mushroom, cardamom, cauliflower, beans and chili) and 753 MT of assorted agricultural products (vegetables, potato, garlic, apple, etc.) were produced. The department provided support in the form of the production materials like irrigation equipment, seeds and seedling, technical inputs, farm tools, etc. These productions are spread across the country and are being implemented adopting integrated landscape approach.

Organic Manure Production

The flagship program supported the up-scaling of the three existing small scale organic fertilizers producers to mid-sized production scale. They produced a total of 49.1 MT of organic fertilizers. Three new vermi-compost productions units in Tsirang and one in Samdrup Jongkhar were also established as well as five small scale compost production units in the eastern LUCs (Nyamed in Mongar, Kheri and Tshowongpoktor in Trashigang, Tsendung in Trashiyangtse and Kherong in Pemagatshel).

TOT and Farmers' Capacity Building

The NOP conducted a series of farmers training and TOT to promote organic farming and facilitate registration and certification. The programs largely focused on building

capacity of farmers and extension officials on organic principles and practices, Bhutan Organic Guarantee System (BOGS) and Bhutan Organic Standards (BOS).

Table 17 ToT and Farmers' capacity building program

Sl	Topic	Participants	Place	Fund Source
	Training of Trainers			
1	Bhutan Organic Standard, LOAS and Organic pest and disease control.	29	Trashigang	NOFP
3	Awareness training on Local Organic Assurance and Bhutan Organic Guarantee System	15	ARDC, Samtenling	NOFP
4	Awareness training on Local Organic Assurance and Bhutan Organic Guarantee System	15	ARDC, Wengkhar	NOFP
5	General overview of organic agriculture, organic seed production, soil fertility management, pest and disease management and Bhutan Organic Guarantee System (including Organic Standard, LOAS and third-party certification)	24	National Seed Centre	NOFP
6	A training of trainer on organic agriculture technologies	33	ARDC, Yusipang	RMS/NOFP
7	Basic principles and techniques of organic agriculture and BOGS	38	Namseycholing resort, Paro	NOFP
8	TOT on BOGS	11	ARDC-Samtenling	NOFP
	Farmers' awareness training			
10	Awareness training on basic organic principles and Practices, BOS and registration and certification.	37	Sergithang, Tsirang	Quinoa program, NOFP
11	Awareness training on basic organic principles and Practices, BOS and registration and certification.	31	DenchukhaSamtse	NOFP

Regional Symposium on Organic Agriculture

A two-day regional symposium on "Organic Agriculture: Youth Engagement and Enterprise Development" was organized at Paro. The event which was funded by ICIMOD discussed developing appropriate institutional mechanisms to foster business partnership using evidence-based technologies. Additionally, the program also provided platform for advocating priorities in organic agriculture development as well as in implementing the National Organic Flagship Programme. Experts from 11 countries attended the program.

3 SUPPORT SERVICES

3.1 Farm Mechanisation

3.1.1 Research

The Department continued its effort into innovations in farm mechanization in its drive to improve existing farming practices and adapt modern technologies into Bhutanese farming context and make farming attractive and drudgery-free.

Innovative Farm Tools and Machineries

The Agriculture Machinery Centre (AMC) develops, builds, improves and innovates on a number of labour and energy saving farm technologies. Some of the technologies that are in their exit phase of evaluation are:

Figure 10 (L -R): Stone picker, power tiller-attached puddler, dry land weeder, multi-purpose potato lifter, and small reversible plough

Testing for Standard and Certification

As in the previous FY, the AMC continued with the testing of a number of farm machinery in collaboration with the Bhutan Standards Bureau (BSB) as part of its mandate to ensure safety and quality of farm machines and implements in the country (see Table 18). These certifications have now become the basis for approval of financial loans with subsidy components for procurement of machinery.

Table 18 Farm machinery tested for certification for private firms

Sl	Firms	Machine	Model	Remarks
1	STCBL	Mini power tiller	SHRACHI-105	completed
		Mini power tiller	SHRACHI-135	completed
2	Sonam Yargyel Enterprise	Mini power tiller	STIHL MH710	completed
3	Depelden Sonam Thruelche Tshonglay	Mini power tiller	Maestro 55P	completed
		Brush cutter	P520BG	completed
4	Sherab Enterprise	Mini power tiller	Husqvarna TF545D	completed
		Mini power tiller	Husqvarna TF230	completed
5	JLW	Rice mill	6N90-F26	completed
			6NJ40-F26	completed
6	Thailand	PEM125Q-BT		completed

3.1.2 Developments

Capacity Building

The AMC's Training Section completed capacity development programs for various stakeholders to help them enhance their technical knowledge as well as encourage individuals in taking up mechanized farming.

Figure 11 Training of various stakeholders in farm machinery

3.2 Plant Protection Services

Highlights of the plant protection services for the past fiscal year by the Department's National Plant Protection Centre (NPPC), Simtokha, besides the general functions like distribution of plant protection chemicals, include:

3.2.1 Research

***Isolation of Trichoderma* and *Phytophthora capsici* spp.**

A total of four major studies were conducted to evaluate the inhibitory effect of eight isolates of *Trichoderma sp.* on four different isolates of *P. capsici* since 2017. These included in-vitro dual culture experiment in laboratory as well as greenhouse studies on growth suppression of *P. capsica* isolates. Isolation of putative strains of *Trichoderma* sp. for control of *Phytophthora capsici* - causal agent of chilli blight was done from soil samples collected from Bjimina in Thimphu and Wangcha in Paro. Plant samples were collected from Kabjisa (Punakha). Eight putative isolates were obtained in 2017.

Bio-assay against *Phythophthora spp* in 2018-19 and 2019-20 indicate that all eight isolates of *Trichoderma sp.* exhibited inhibition of more than 75% on all four isolates of *P. capsici.* Subsequent greenhouse bioassays in 2018 and 2019 which evaluated efficacy of the isolates of *Trichoderma* sp. against the four isolates of *P. capsici* combined as one, showed reduced area in infection which rarely went below 20%. *Trichoderma sp* is also indicated no adverse effect on plant growth.

Figure 12 (L) Plant inoculated with *Trichoderma* alone (left) and inoculated with *P. capsici* in presence of *Trichoderma* sp. (right) at 7 days after inoculation. (R) Sporangia: globose (left) and lamoniform (right) with papillate (black arrow) and pedicel (white arrow) observed under compound microscope (400x).

Additional findings include that of the 13 sets of primers used for this molecular study only one set, the ITS primers worked indicating the need to design primers for these native isolates (Figure 13). For *P. capsici*, two primer sets: PC1 and PC2, and CAP FW & CAPRV1 & 2 indicated positive results (Figure 13). These are *P. capsici* specific primers.

Figure 13 PCR result of (left) isolates *Trichoderma* sp. using ITS; and (right) isolates of *P. capsici* using primers CAP FW & CAPRV1 & CAPRV2

Evaluation of Potassium Phosphonate against Phytophthora capsici

Laboratory and greenhouse experiments were conducted to assess the effectiveness of potassium phosphonate – a potassium salt of phosphonic acid with systemic effect against fungal and fungal-like pathogens – against *P. capsici.* Two isolates of *P. capsici* were cultured on carrot agar medium amended with potassium phosphonate powder at varying concentrations (0.2 – 0.5%). Greenhouse evaluation included four separate experiments, one for each isolate of *P. capsici* that involved chilli plants (local variety ema 'oru') inoculated with 10% (w/w) *P. capsici* inoculum being sprayed three times at 7 days interval, with the first spray commencing at the time of transplantation at 0.2%, 0.3 %, 0.4%, and 0.5% of potassium phosphite. Control plants were sprayed with distilled water.

Results showed that potassium phosphite at 0.02 -0.05 % can inhibit growth of *P. capsici* under laboratory condition. However, observations indicate that same concentrations may not be sufficient to reduce disease severity under field condition as demonstrated by the inconsistent levels of disease severity in the greenhouse. For stable reduction of disease severity across all isolates of *P. capsici*, increase in potassium phosphite concentration may be desirable.

PCR Analysis of Citrus Samples for HLB Pathogen

The NPPC has been screening citrus plants for huanglongbing (HLB) pathogen from the National Citrus Repository at the ARDSC-Maenchuna, Tsirang since it first started the program in 2017. Until June 2020, a total of 625 samples were tested against the targeted minimum of 300. In the first batch PCR test results showed that out of the 37 stock plants tested, 18 were cleared for mass propagation while 12 were recommended for destruction. Remaining varieties shall be re-sampled and tested. Test for remaining

batch included 19 varieties (stock plants) of which 15 were cleared for mass propagation, and the remaining plants earmarked for re-test.

Effectiveness of Super Grain Bags against storage Pests in Maize

A study to revalidate the effectiveness of super grain bags in preventing storage losses due to storage pests was conducted in Khameythangkha, Darla Gewog in Chukha, Kilikhar and Thangrong in Mongar and Samtenlling in Sarpang. Storage insect pest infestation levels in maize stored in super grain bags versus traditional storage approach by farmers (maize cobs hung under the roof) were compared.

The study found significant differences in the infestation level of maize stored in super grain bag (mean infestation level =13.9095) and under the roof (mean infestation level =79.73), indicating that maize stored in super grain bags are infested less by storage insects as compared to the traditional storage methods. The main storage pests observed in maize stored in super grain bag and under the roof were maize weevils (*Sitophilus zeamais*e), flour beetle *(Tribolium castaneum)* and Angoumois grain moth *(Sitotroga cerealella).*

Impact Assessment of Electric Fencing

A survey was conducted to understand the effectiveness of electric fence (EF) against various wild animals. The survey which covered 199 sites in 17 dzongkhags also involved verification of technical parameters of the fences. The assessment is conducted in two phases with the preliminary report already in place followed by a detailed publication in the coming 2020-21 financial year.

More than 77% of the electric fences are owned by the community and only about 12% are privately owned. However, EF has had huge socio-economic impact on all individuals in the community in that it has brought about huge relief from the toll on their physical and mental health from standing guard over their crops for years on end as well as the trauma from losing crops to wild life. EF is found most effective against wild boar (73%) followed by cattle (69%). Though monkeys are one of the major vertebrate pests of crops, 42% of the respondents found EF to be ineffective against them. Similarly, EF is not effective against porcupine (38%). About 15% respondents in the southern dzongkhags indicate that EF is an effective deterrent against elephants.

In spite of all the benefits, around 12% of the EFs surveyed are found to be non-functional. Some of the issues observed are:

- **Technical:** faulty connection with energizers especially for solar powered fences; poor or lack of separate earthing; lightning damage of energizers, and disengagement of electric current during off-season leading to damage of wires by humans and domestic animals – important to maintain continuous current flow.

- **Illegal activity:** direct use of electricity from home without energizer was observed in Eusu (Haa) and Bartsam and Kanglung (Tashigang) posing serious health hazards to both humans and animals.

- **Fence materials:** difficulty in getting wooden pole replacements. Preliminary study on HDPE pipes by ARDC, Wengkhar and manufacture of recycled plastic poles by private agencies need to be tested for durability and cost benefit analysis conducted.

3.2.2 Developments

Pest Surveillance

As part of its regular annual services, the NPPC carried out pest surveys and surveillance across the country on major crops to record and help farmers' make appropriate and timely decision on management of important insect pests and diseases. Some of them, in gist, include:

a) Wheat and Barley Rust

Wheat rust monitoring survey carried out in Trongsa and Thimphu dzongkhags at various stages of crop maturity found severe stripe rust incidence as compared to the previous year in Trongsa. Trongsa however, recorded low incidence and severity of brown rust in barley. Yellow rust severity and incidences in surveyed areas of Thimphu were low.

b) Rice Blast

A nine-day survey in selected gewogs of Paro, Thimphu and Punakha Dzongkhags monitored rice blast disease in different varieties of rice. Overall, of the fifteen varieties grown, five (IR-64/Aupa Thungku, Yusi Rey Kaap, Jakar Rey Naap, Gyambja, Dhasum and Tan Tshering) were infected while rest recorded free of the disease. Among these five infected varieties, disease incidence and severity were observed to be high in IR-64 while Gyambja, Dhasum and Tan Tshering recorded low incidence and severity.

c) Ear Cutting Caterpillar

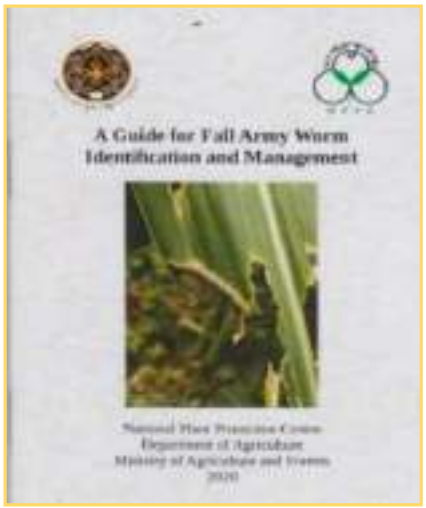
Monitoring survey of ear cutting caterpillar in Chuzergang, Dekiling and Senghe gewogs in Sarpang observed very high (nearly 95%) destruction of panicles in Senghe Gewog. The gewog had the most pest population at larval stage which is known to be the most destructive stage. The highest pest population was recorded in Dekiling. However, the crop loss was low as compared to Senghe Gewog as majority of the pest were already in their pupal stage. Chuzergang had the least damage. Pheromone traps were installed to monitor adult moth population as well as identify the army worm

types present. Two different types of ear cutting caterpillars were observed all over Sarpang. They are suspected to be *Mythimna* and *Spodoptera* spp.

Figure 14 Two species of ear cutting adult moths as observed in Sarpang

Guides for Fall Army Worm Identification and Management, and Sunrice® Herbicide

Fall armyworm (FAW), *Spodoptera frugiperda* (J E Smith) is a very important invasive pest species native to tropical and subtropical America, and has been spreading rapidly through Africa since 2016. In Bhutan, FAW was first detected and identified through morphological and molecular analysis from maize fields in Punakha in September, 2019. Molecular analyses of specimens from Punakha indicate it to be the "corn" strain that primarily prefers to feed on maize.



It is a serious pest due to its polyphagous habit of feeding on over 80 different crop species. Since the pest is of tropical origin and unable to undergo diapause or survive cold conditions, it may not survive the cold winters or overwinter in the temperate regions of Bhutan. However, FAW can establish itself as a permanent, multigenerational pest in the southern belts from which it can possibly migrate to the interior parts of the country with the availability of suitable host plants coupled with favourable climatic conditions.

A robust field monitoring, surveillance and scouting system is required to manage the pest, and hence the need to train farmers and extension staff on identification and management strategies. The NPPC has developed a guide that comprises information on identification, damage symptoms and management strategies of FAW. Copies have

been distributed to all dzongkhags as well as ARDCs. It is also available on the centre's webpage at www.nppc.gov.bt.

A technical brochure has been developed and published to guide extension agents and farmers on preparation of Sunrice ® herbicide solution, spray techniques, spray timing and other essential pointers for effective control of target weeds in rice. The brochure can be viewed online on NPPC's website and printed copies can be picked up from the centre's office at Simtokha.

***Farmer Demonstration on Ethoxysulfuron herbicide* (Sunrice®)**

Following successful efficacy studies on ethoxysulfuron both in-vitro and in farmers' field in preceding years, the centre organized and conducted practical demonstration on the preparation of recommended spray solution, and appropriate spraying methods for farmers in five eastern dzongkhags. A similar demonstration in the south was conducted in Ugyentse and Yoeseltse gewogs in Samtse. In central Bhutan, rice growers in Nubi Gewog, Trongsa participated in the program which involved use of the herbicides at recommended dosage at various growth stages of weeds.

Capacity Development

In response to Gasa Dzongkhag Agriculture Sector's request, a four-day Training of Trainers (ToT) on electric fencing (EF) system was conducted. It was aimed at enhancing the technical capacity of dzongkhags on installation and management of electric fences. Forestry officials from the dzongkhag also attended. In addition to working principles, installation process, accessories and materials estimates, electric and solar systems, the participants also familiarized themselves with identifying and troubleshooting common EF issues.

Figure 15 Capacity building program on electric fencing system in Gasa

Community Awareness on Chinese Citrus Fruit Fly Management

The NPPC in collaboration with the ARDC- Wengkhar initiated community awareness programs in six different citrus growing sites in Lhuentse (Metsho, Gangzur, and Minjey gewogs) and Mongar (Drepong and Mongar gewogs) to:

a) Build awareness on citrus fruit fly management and advocate collection and destruction of dropped citrus fruits as a regular scheduled activity.

b) Demonstrate different methods of collection and destruction of dropped citrus fruits and use of lures to monitor other fruit fly species.

c) Train farmers on major insect pests, disease and weeds of citrus.

Figure 16 Citrus fruit fly management advocacy program

Plant Protection Services

The NPPC supplied a series of different types of plant protection (PP) products to help manage crop pests and diseases. These PP products are broadly categorized into insecticide, fungicide, herbicides, nontoxic PP products and rodenticides. About 472.70 MT or kilolitres of PP products were supplied from July 2019 to June 2020 (see Table 19). The centre also provided a range of diagnostic and advisory services to farmers and other growers across the country on a number of pest and diseases issues. It also includes laboratory diagnostics.

Table 19 Quantity of plant protection products supplied by NPPC in FY2019-20

Sl	Chemicals	Total Procured (Kg or L)	Quantity supplied (kg or L)	Stock balance (kg or L)
1	Insecticide	6,689.0	3,439.0	3,250.0
2	Fungicide	10,534.0	4,125.0	6,409.0
3	Herbicide	660,929.0	458,809.0	202,120.0
4	Rodenticides	8.6	8.6	0.0
5	Non-toxic/Biopesticides	12,883.0	6,321.0	6,562.0
	Grand total:	**691,043.6**	**472,702.6**	**218,341.0**

Pest Risk Assessment

Following the appointment of a four-member technical working group for Pest Risk Analysis (PRA) with lead members entirely from the centre, three major PRA tasks were completed with reports duly submitted. They include:

a) Revision of pest information for apple, mandarin and potato in preparation for export market in Thailand.

b) PRA for okra, onion and tomato import from India in keeping with procedures of the European and Mediterranean Plant Protection Organisation (EPPO) on quarantine pests and Biosecurity Import Risk Analysis Guidelines for Australia. Ten pests were identified as quarantine risk from importation of these commodities and accordingly risk management measures proposed and put in place.

c) Mitigation measures on quarantine pests of apple, mandarin and potato that the GOI identified as possible threats to India.

3.3 Post Harvest Program

3.3.1 Research

Sprout Suppression in Potatoes

A major constraint in storing potato in the country is sprouting. Use of chemicals to inhibit sprouting discouraged due to health and safety concerns, and adverse impact on environment. This study assessed the inhibition/suppression effect on potato sprouting by ethylene released apple, and analyzed subsequent quality changes in potato when stored together with apples. The study involved storage of potatoes with apples in apple cold stores at 2-4 ˚C for 22 weeks and potatoes stored in cold room without apple at the same temperature range as control.

Gradual physiological weight loss of potato was recorded irrespective of the treatments but tubers stored with apple had lower rate of loss. Final sample weights were recorded at 10.21 kg and 11.48 kg respectively from its initial weight of 12 kg. Control tubers initiated sprouts at week 6 and attained measurable sizes ((>5 mm) by week 16. The sprouting rates were 56.46 %, 42.23 % and 71.75 % for weeks 18, 20 and 22 respectively. The average lengths of the longest sprouts for the same recording weeks were 0.93 cm, 1.2 cm, 1.39 cm and 1.55 cm respectively. No sprout initiation was recorded in tubers stored with apple during the entire storage period. The study indicates possibility of long-term storage of potato seeds together with apples in reducing sprouting and enhancing potato seeds quality.

Post-harvest Handling Losses of Quinoa (Chenopodium quinoa)

Following its introduction in 2015 quinoa has gained popularity and its cultivation as a nutrient dense cereal crop is picking up. The NPHC conducted studies in Mongar (Lingmethang, Tzenzebi, Yongkola) to assess quinoa losses at different post-harvest stages. Field drying loss of 1.4% and threshing loss of 2.3% with a mean of 3.7% was recorded from Lingmethang. Field drying and threshing losses of 6.5% and 3.4% respectively with a mean of 9.9% was recorded for Yongkola while in Tzenzebi, the mean losses increased to 14.7% including field drying loss recorded at 7.1% and threshing loss at 7.6%. Weight losses during drying were 3.4%, 4.7% and 5% for samples from Lingmethang, Tzenzebi and Yongkola, respectively. Weight loss during storage was very minimal at 0.35% while weight loss after de-husking was 19.2% for samples tested from Lingmethang. This offers avenues for interventions in improving field drying and threshing operation to help reduce losses.

Shelf-life, Quality and Post-harvest Losses of Pear

Studies were conducted at Paro and Lingmethang (Mongar) to determine the handling losses and shelf-life of pear fruits during storage in cold room and at room temperatures. Results demonstrate that low temperature storage of pear (2-6 ˚C) greatly enhanced pear storage life for 49-56 days. Conversely, pear quality at room temperature storage started degrading from 14 days of storage. Low temperature storage helped reduce physiological weight loss while maintaining better and attractive visual quality. It also slowed the process of climacteric respiration, thereby, retaining fruit firmness.

Maize Syrup Extraction and Product Development

Study on maize syrup extraction and product development were conducted at IFPP Lingmethang and Shumar with an objective to determine the quantity of maize syrup from different varieties, syrup extraction methods and the use of syrup for product development. Starch recovery rate was found the highest in Khangma Ashum at 180 ml per 3 kg of maize followed by 170 ml for HTMA (heat tolerant maize) while the lowest was recorded for Yangtsepa at 150 ml. The total soluble solids were 23.7 ˚Brix, 32 ˚Brix and 27.8 ˚Brix for Khangma Ashum, HTMA and Yangtsepa, respectively. Manual extraction of syrup was inefficient and did not provide quality syrup.

Comparative Studies on Curing Methods and Quality Changes in Areca Nut

Comparative studies were conducted at ARDC-Samtenling to see the feasibility and the most convenient of areca nut curing methods in Bhutan. Freshly harvested areca nuts were stored in pit enclosed with polyethylene, in barrels at ambient condition, polyethylene enclosed with jute bag stored in ambient conditions, and immersed in 0.1% of sodium benzoate and 0.2% of potassium metabisulphite. No significant differences were observed in weight loss and sensory assessment when nuts were

evaluated after nine months. However, based on farmers' affordability, pit method with black polyethylene was found the most convenient.

Assessment into Ginger Storage Structures

Gingers are stored in traditional pit method with short storage life. Traditional pit storage was compared with storage structures designed by the NPHC. The lowest physiological loss in weight (PLW) was recorded from Zero Energy Cold store (ZECS) chamber at 6.2% in the 3rd month followed by gingers in pit type storage. Traditional storage resulted in a PLW of 9.8%. Although PLW increased over the storage period for gingers in all storage structures, those stored in ZECS had significantly lower shrinkage at 7%. Rate of shrinkage in ginger from ZECS chamber was slow over the 3-month storage period, but the number of decayed rhizomes was higher in ZECS chamber and significantly different from other structures. Rhizome sprouting and sprout lengths were lowest for ginger stored in ZECS while traditional type storage resulted in higher sprouts. Ginger storage in ZECS with some modifications to reduce rhizome decay could provide an effective solution in maintaining quality during storage compared to traditional type.

Product Development

A number of products have been developed by the National Post Harvest Centre (NPHC) to help value-add and diversify farm products. In the past year, the centre, along with its food processing plants in Dagapela, Goling, Lingmethang and Shumar developed several products on trial. They are, in each category of crops, fruits (11 products), vegetables (12 products), cereals (11 products), and other crops (12 products). Some of the processed products developed include bread, cake, candy, chips, chutney, cookies, corn starch and syrup, flakes, herbal drink, jam, muffin, noodles, papad, paste, pickle, soup, syrup, tea, and wine.

3.3.2 Developments

Transfer of Post-production Technologies

Simple and effective postproduction technologies developed by the center were disseminated in different parts of the country on need basis. The following technologies were established in collaboration with various stakeholder and funding agencies:

Table 20 Post-production technologies disseminated

Technology	Place	No	Remarks
Maize curing and storage shed	Saling (Mongar), Tshangkha (Dagana), Shumar, Dungmin (Pema Gatshel)	7	In collaboration with Dzongkhag Agriculture Sectors
Onion curing and storage shed	Shumar and Yurung Pema Gatshel)	2	In collaboration with Dzongkhag Agriculture Sectors
Improved household electrical dryers	Dunglagang, Tshokhorling, Kilkhorthang Gewog (Tsirang), Singye, Chudzom, Pelrithang, Dekilang, Chuzegang (Sarpang)	12	In collaboration with Dzongkhag Agriculture Sector with fund support from NoFP

3.4 Seeds and Plants Development Program

3.4.1 Developments

The National Seed Centre (NSC) has completed the 2nd year of the 12th Five Year Plan on a high note with an overall physical achievement of 103% against its annual targets. Sales volumes saw an increase as a direct result of the Department of Agriculture's mass vegetable production drive initiated as part of the nation's response to the Covid-19 pandemic. Gross revenue for 2019-20 fiscal year stood at Nu. 172,728,856.85. The centre also completed major infrastructure work that include irrigation system at Samtenling, processing and packing machinery, renovation of staff quarters, repair of water pond in Bonday, green house structures at Jachedphu, and set-up of soil sterilization unit at Samtenling.

Figure 17 Citrus propagation houses at Jachedphu farm (Trashi Yangtse)


Figure 18 Dragon fruit seedlings at NSC farm in Samtenling and maize seeds at Jachedphu farm.

Seeds Production and Supply

A total of 616.27 MT seeds of vegetables, cereals, oilseeds and seed potatoes were produced on-farm, procured from Registered Seed Growers (RSGs) or imported and supplied to farmers across the country in the 2019-20 reporting year by the NSC, Paro. Most open pollinated variety (OPV) seeds of cereals, oilseeds and vegetables seeds are produced on farm and by RSGs while hybrid vegetables are mostly imported. The centre saw a huge spike in seeds demand following the Covid-19 pandemic. Vegetable seeds supply surpassed its annual target, and although the centre faced huge logistic difficulties in importing vegetable seeds from the US, Japan and India due to lockdown, it managed to acquire adequate quantities to support the ministry's primary intervention of ensuring food self-sufficiency against the backdrop of this pandemic. Potato seed demand also increased due to the recently released nutrient dense and high yielding variety Yusimaap.

Table 21 Seeds supplied and revenue generated from the sales in 2019-20

Sl	Commodity	Type/Variety	Quantity (Kgs)	Amount (Nu.)
1	Vegetables seeds	All types	18,210	41,940,645.90
2	Cereals seeds	Maize, wheat, paddy	154,831	7,880,114.00
3	Oilseeds	Mustard, Soybean	15,783	1,552,805.00
4	Seed potatoes	Desiree	380,920	10,253,794
5	MaPs & spices	Turmeric & ginger	46,530	3,966,345.00
	Total		**616,274**	**65,693,703.90**

Tissue Culture and Micro-propagation

Following its strengthening in 2014, the centre's tissue culture program has made impressive stride. In the last year, the NSC has produced and supplied 7,230 numbers of the popular banana variety Grand Naine. Tissue culture banana has successfully helped fulfill the country's banana seedling demand within three years. Other achievements for the tissue culture and aeroponic labs include production of 60 kg of mini-tubers, 15,000 micro-tubers of Desiree potato to support the purification flow of Desiree seed potato in Phubjikha farm. Additionally, 5000 nos. of apple rootstock MM106 were produced through tissue culture to aid apple multiplication at Jewphu farm.

Fertilizers Supply

A total of 3,374.15 MT of fertilizers were procured and supplied across the country generating revenue to the tune of Nu.92.95 million. An assorted number of different industry standard fertilizers are being supplied in an effort to help farmers enhance crop yield and productivity (see Table 22).

Table 22 Sale and supply of chemical fertilizers

Sl	Fertilizers	Unit	Qty sold	Amount (Nu)
1	Suphala, NPK,15:15:15	Mt	1,351.91	50,723,663.20
2	Urea 46%N	MT	1,441.975	30,711,832.80
3	SSP (16%P2O)	MT	568.8.00	11,114,352.00
4	MOP (60%K2O)	MT	6.20	283,556.00
5	Borax (20%boron minimum)	MT	0.51	95,676.00
6	DAP (18%N46%P2O)	MT	1.45	
7	Bone Meal	MT	0.55	22,616.00
	Sub- Total		**3,371.40**	**92,951,696.00**

3.5 Soil Services Program

3.5.1 Research

The National Soil Services Centre (NSSC) carried out a number of activities intended to build research capacity of the Soil Services Program as well as help better understand and build knowledge and information on soil and nutrient management. They include:

IPNM Trials

To promote integrated soil nutrient management and to increase production, the NSSC in collaboration with respective dzongkhags conducted integrated plant nutrient management (IPNM) trials in maize, apple and citrus in Dagana, Sarpang and Pemagatshel dzongkhags. Yield comparisons were made between IPN managed or recommended practice and farmers' practice. Differences in yield of +11.04 kg/tree in apples and 707 kg/acre in citrus were observed.

Green Manure Effects on Paddy Yield

Considerable improvement in yield was observed in rice fields supplemented with green manure Daincha *(Sesbania aculeata)* (see Table 23). Assessments were conducted in paddy fields in Samdrup Jongkhar, Sarpang, Tsirang and Samtse. Results also show higher potassium (K) and phosphorus (P) in rice fields managed on farmers' practice where they incorporate FYM application at the rate of 1.5 MT per acre.

Table 23 Yield differences in rice grain yield with and without Dhaincha

Paddy variety	Yield kg/acre		Yield difference (kg/ac)	Site
	With Dhaincha	Without Dhaincha		
Local	2171.2	1332.7	840	S/Jongkhar (Pemathang & Phuentshothang Gewog)
BhurKhamja 1	1516.5	1251	270	
Rangjit	1401	1137	260	Dagana (KarmalingGewog)

Figure 19 Marking crop cut area (L); Visual difference in paddy plant colour

Soil Survey and Land Evaluation

Soil survey of reconnaissance scale was carried out in Bumthang, Punakha, Wangdue, Dagana, Sarpang and Zhemgang to collect baseline soil data from cultivated areas, classify soils and generate soil map of same scale by 2023. The survey covered 203 profile points in all. The department targets to put together a general soil map for the whole country by 2023.

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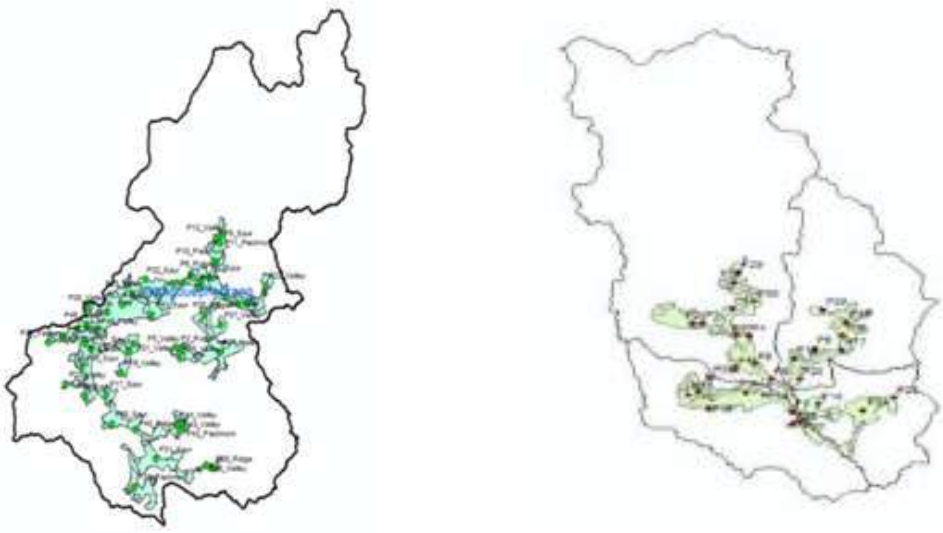

Figure 20 Profile points in two dzongkhags of Wangdue (L) and Bumthang (R)

Similar survey was also conducted as part of the User Right Certificate (URC) program to identify feasible state land for allotment to unemployed youths in designated areas of Lameythang, Gumbadangra, Copibari and Bijanbari under Samtse Dzongkhag. Potential for farming in these areas were assessed using Land Capability Classification (LCC) which is a systematic method of determining the ability of land to sustain a range of specified uses without causing significant long term degradation.

Further, detailed soil surveys were carried out in Tsendagang and Tsangkha in Dagana covering a total of 92 acres as part of the National Organic Flagship Program (NOFP) to assess feasible areas for organic farming.

3.5.2 Developments

In delivering effective soil and nutrient management services to growers and other stakeholders round the country, the Soil Services Program implemented the following in the past one year:

Soil Investigation

In this reporting period, the NSSC completed soil investigation reports for orchard in Majathang (Mongar) and at the quarry rehabilitation site in Taksha, Wangdue. Soil investigation at Majathang focussed on assessment for organic farming while at Taksha the study looked at soil conditions for possible tree plantation as part of rehabilitating the quarry. Recommendations include addition of at least 50 cm of topsoil evenly at the quarry site along with adequate fertilizers and water to enhance the plant growth in the initial stages.

Soil and Plant Analytical Services

Analysis of some 7,094 samples which included 7,056 soil, 31 plant and 7 irrigation water samples were carried out by the Soil and Plant Analytical Laboratory of the NSSC in 2019-20 reporting year (see Figure 21). Chemical analyses and analysis for soil bulk density were the two main components. Samples analyzed come from a range of clients that include farmers, agriculture extension, research centres and academia.

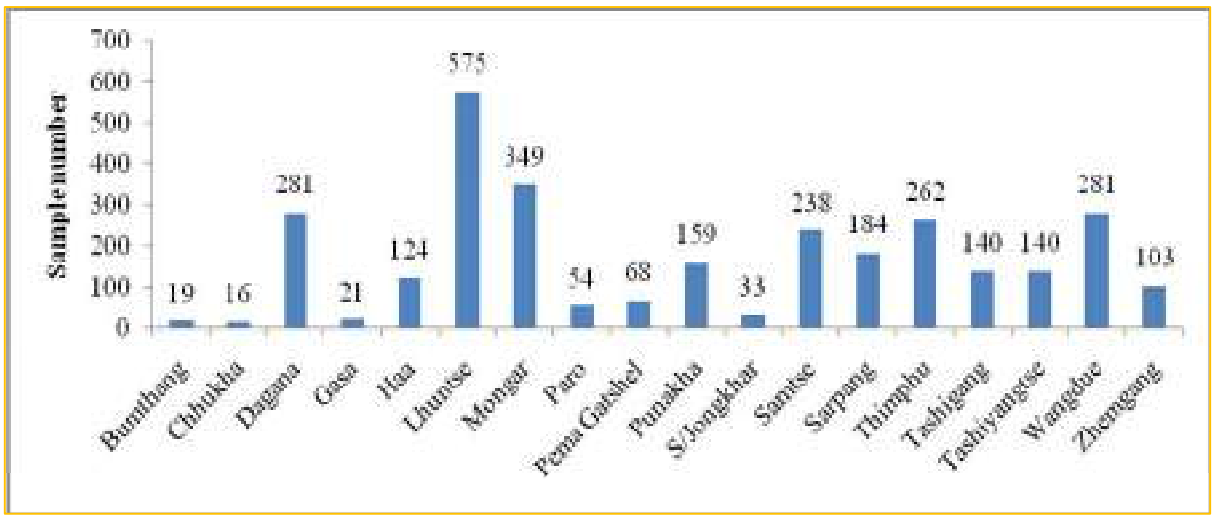

Figure 21 Number of samples analyzed for chemical and bulk density

Sustainable Land Management

Some of the major interventions in sustainable land management carried out by the NSSC for the year 2019-20 with fund support from GEF- LDCF, BTFEC and GCF are as included in the following tables. These also include ad-hoc technical assistance provided to dzongkhags for agriculture land development (ALD) for commercial agriculture as part of the initiatives taken by the department and the MOAF in responses to Covid-19 pandemic.

Table 24 Land management programs supported through GEF-LDCF

Sl	Activity	Progress	
		Physical	Financial (Nu. Mn)
1	Demonstrate different SLM, IPNM and Climate Smart Agriculture approaches in 3 SLM model villages of Nimshong	74.3 acres (160 HHs)	0.785
2	Monitoring and Evaluation (consultation) on the benefits on bench terracing in Trongsa and Haa	173 HHs	0.097
3	Maintenance of soil erosion plots at ARDC Samtenling	1 No.	0.030
4	Agriculture Land Development (ALD) - bench terracing - in Trongsa, Haa, Zhemgang and Mongar	100.42 acres (147 HHs)	2.066
5	Conduct soil survey (Punakha Reconnaissance Soil Survey)	-	0.471
6	Print and publish SLM related materials (sets)	15 sets	0.098
7	Exchange visit for the gewog and NSSC staff toThailand.	22 staff	3.340
			6.887

Figure 22 New terraces developed in Nubi, Trongsa

Table 25 Land management programs supported through BTFEC

Sl	Activity	Physical Progress	Budget (Nu. Mn)	Exp (Nu.Mn)
1	Planting materials for SLM and bio-engineering activities (napiergrass slips, fodder tree seedlings, bamboo rhizomes, etc.)	Fund utilized for land development at Yarphu Chiwog	0.146	0.139
2	Incentives to farmers for constructing contour stone bunds and terraces	part of the fund utilized for land development at Yarphu Chiwog	0.651	0.651
3	Organized World Soil Day on 5th Dec 2019 to create awareness on the importance of soil, SLM, and LDN at Khamdhang Gewog, TrashiYangtsi	900 participants	0.400	0.400
4	Prepared a musical MTV highlighting the services being provided by NSSC	one MTV theme song	0.050	0.049
	Monitoring & assessment of SLM project activities in the field	two monitoring visits	0.042	0.041
5	Organized project completion GT to present SLM Project outputs and findings	140 participants including MOAF staff, representatives from the BTFEC, LG and farmers	0.063	0.062
6	Publication of SLM project completion report	SLM training materials published	0.050	0.049
			1.402	**1.391**

Table 26 Land management programs supported through GCF

Sl	Activity	Physical Progress	Budget (Nu. Mn)	Exp (Nu.Mn)
1	Participatory SLM Action Planning in selected Climate Smart Villages	SLM Action Planning carried out at 7 Climate Smart Villages in Punakha, Wangdue, Dagana, Tsirang, Sarpang, Trongsa and Zhemgang	0.531	0.458
2	Reducing Land Degradation (soil erosion) and improving land productivity through: Contour hedgerows	About 61 acres of contour hedgerows established in Tsirang, Dagana, Sarpang , Samtse	0.924	0.882

3	Improvement of existing Soil Erosion Plot	1 additional replicate consisting of 5 plots constructed at ARDC Yusipang)	0.17	0.169
4	Capacity strengthening to farmers and extension officers on SLM	Mostly deferred due to Covid-19	0.533	0.174
			2.158	**1.683**

ALD for Commercial Agriculture – Response to Covid-19 Pandemic

Like elsewhere the Covid-19 pandemic has impacted Bhutan by largely affecting the livelihoods of those working in sectors that suffered directly from the pandemic like tourism and hotel sectors. As part of the many measures initiated to provide economic relief to affected groups, the DoA put together commercial and urban agriculture – vegetable farming in particular - for interested individuals and groups. In total, about 140 acres of fallow land have been developed and brought into cultivation for laid-off employees as well as groups that included youths. Technical support in land management was also provided as part of the initiative.

Table 27 ALD for commercial agriculture in response to Covid-19 impact on livelihoods

Sl	Activity	Area (ac)	Location	Dzongkhag
1	Land development (dryland terracing)	15.0	Jadingkha, Mewang	Thimphu
2	Land development (dryland terracing)	2.0	Dalukha, Mewang	
3	Land development (land clearing, ploughing and preparation))	3.0	Dodena, Kawang	
4	Land development (Ploughing, consolidation and bed making)	11.0	Babena, Kawang	
5	Land development (dryland terracing and sub-surface drainage)	2.4	Chamina, Kawang	
6	Land development (drylandterracing)	10.0	Changtagang, Kawang	
7	Land development (dryland terracing)	2.3	Nimashong, Kawang	
8	Land development (clearing, ploughing, terrace consolidation)	6.0	Khariphu, Mewang	
9	Land development (ploughing and bed making)	5.0	Hejo, Kawang	
10	Land development (field clearing, ploughing and bed making)	1.0	Taba, Kawang	

11	Land development (dryland terracing)	25.0	Bama, Tshocheykha & Zangleykha, Gney	
12	Land development (field clearing, ploughing and bed making)	33.0	Wobthang, Tang	Bumthang
13	Land development (field clearing, terrace consolidation, ploughing and land preparation)	24.0	Lingtoed, Langthel	Trongsa
	Total	**139.6**		

Figure 23 Land developed at Tang Gewog (before and after)

4 SCHOOL AGRICULTURE PROGRAM

The School Agriculture Program (SAP) is a collaboration between the Department of School Education, Ministry of Education (MoE) and the Ministry of Agriculture & Forests, and has been functional since 2000. The Ministry of Agriculture & Forests is the lead agency. The program now focuses on supplementing food and nutrition in school feeding program to help address shifting priorities.

Program Expansion and Production

With 12 new schools joining the program, the SAP currently supports 344 schools, amongst which 83 schools run poultry programs that produced a total of 7,96,170 eggs that were consumed by students in school mess, and contributing to the school SAP, a revenue of Nu. 9.890 Million. 85 schools with piggery program also produced a total of 85.17MT of pork. In terms of fresh vegetables, 300 vegetable demo gardens in these schools produced 103 MT of fresh green vegetables and potatoes (see figure below).

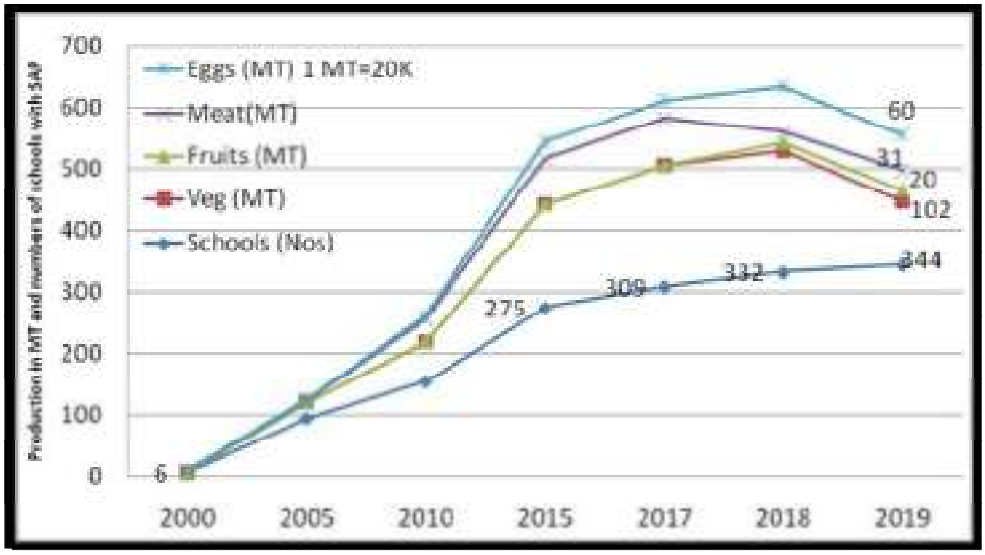

Figure 24 Food production by SAP schools (2019-21)

Focal Agriculture Teachers' Capacity Development

A weeklong crash course on Integrated Organic Agriculture was organized at the College of Natural Resources (CNR) in January 2020 for 31 school teachers. The program was financially supported by the National Organic Flagship Program (NoFP). Similarly, a batch of 17 school principals and focal teachers from successful SAP schools were provided advanced agriculture training at the RDTC in Zhemgang with fund supported from WFP. Thirty two teachers from 28 schools also attended a week-long training program on integrated farming at the College of Natural Resources, Lobesa.

World Food Day

The program successfully organized the World Food Day with the global theme "Our Actions are Our Future; Healthy Diet for a Zero Hunger World" on 16 October 2019 in Sakteng, Trashigang. Hon'ble Sanam Lyonpo presided over the program as chief guest, accompanied by Zhabto Lyonpo and around 2,000 students and general public. The day-long program also included the SAP Awards. All awards were accompanied with cash prizes, certificates and rolling trophies from the FAO, WFP, Asia Pacific Natural

Agriculture Network (APNAN) and OSPS.

Figure 25 World Food Day celebration & SAP Awards 2019

5 FARM INFRASTRUCTURE

The Agriculture Engineering Division (AED) is tasked to oversees all infrastructure development programs of the department and the ministry which involves building new irrigation systems, rehabilitating old ones, coordination of farm road programs and civil construction works. Highlights of major activities for the reporting year carried out in collaboration with the engineering sections attached with ARDCs and other stakeholders are summarized as follows.

5.1 Farm Roads and Land Development

The department's Central Machinery Unit (CMU) in Bumthang continues to assist in improvement and construction of farm roads and major land development programs. For the last fiscal year, close to 400 km of farms roads were constructed along with land development of 1,300 Ac for paddy cultivation. Land development include developing new terraces or widening them in addition to consolidating smaller terraces to bigger sizes ones to facilitate use of farm machinery. Additionally, the Engineering Division also developed over 50 Ac of land in Thimphu as part of the department's initiative on vegetable farming for affected individuals in following the Covid-19 pandemic.

5.2 Farm Road Bridges

The department is also involved in feasibility studies, design and costing, and supervision to some extent of all farm road bridges in the country. In the last reporting year, the department assisted in the detailed survey and design of about 50 farm roads

(FR) bridges. Most are under construction while some have been completed. Following are some of the major farm road bridges survey and designed for various dzongkhags with the spans longer than 100 feet.

Table 28 Major infrastructure development that DoA provided TA

Sl	Work type	Beneficiary	Remarks
1	Construction of Jimichhu Bailey Bridge, 120 ft	Bongo, Chhukha	Implemented by zongkhag
2	Construction of SingaarChhu Bailey Bridge, 120 ft	Dungna, Chhukha	Implemented by zongkhag
3	Construction of Diana Khola Bailey Bridge 180 ft	Norbugang, Samtse	Implemented by zongkhag

5.3 Buildings Program

The DoA also caters to the construction and maintenance needs of all RNR construction works under the ministry. Some of the major constructions works where the department helped with the design, estimates, tenders, evaluation and supervision were:

Table 29 Major building construction works by AED for 2019-20

Sl	Type of works	Beneficiary	Amount (Mn Nu)
1	Construction of Divisional Forest Office, Gedu	DoFPS	10.01
2	Construction of office building for Jigme Khesar Strict Nature Reserve (JKSNR), Haa	DoFPS	20.44
3	Construction of fencing works for bear enclosure, Kabisa	DoFPS	5.76
4	Construction of laboratory building for National Mushroom Centre (Wangchutaba)	NMC, Wangchhutaba	18.12
5	Construction of Range Office building at Jutsiphu, Paro	DoFPS	3.48

5.4 Irrigation

The Department of Agriculture's Irrigation Section is responsible for building appropriate irrigation systems to enhance crop production, food and nutrition security of rural communities and RNR sector growth. Major irrigation systems constructed and renovated for 2019-20 are as follows (see Table 30).

Table 30 Major irrigation systems constructed and renovated 2019-20

Sl. No.	Name of Scheme	Length (km)	No. of beneficiary Hhs	Command Area (Ac)	Expenses (Nu. in Million)	Funding Agency
1	Construction of Rateykhola Irrigation Scheme, Dekiling (Sarpang)	3.50	187.00	338.00	31.20	FSAPP
2	Construction of Laringkhola Irrigation Scheme, Gakiling (Sarpang)	8.50	80.00	310.37	37.80	FSAPP
3	Construction of Taraykhola Irrigation Scheme, Norbugang (Samtse)	11.00	270.00	647.96	43.26	FSAPP
4	Construction of Birkulo Irrigation Scheme, Dophuchen (Samtse)	2.00	26.00	50.00	7.80	FSAPP
5	Construction of Langpa_Nobgang Irrigation Scheme, Sama (Haa)	10.00	60.00	200.00	15.00	GEF
6	Construction of Lunakha_Bejana (Phendey) Irrigation Scheme, Talo (Punakha)	25.00	430.00	1000.00	33.83	GEF
7	Construction of Yabrang -Saling Irrigation Scheme, Phongmey (Trashigang)	7.80	170.00	500.00	36.00	RDCCRP
8	Construction of 2nd Phase pop up irrigation system at Royal Chhipta Farm (Taba)			8.00	4.60	RGoB
9	Construction of irrigation system for nursery site and dryland at Wirelesspang, Dechhenchholing and Trashichhoedzong Garden Landscape Development Project			12.00	1.00	RGoB
10	Construction of Drip Irrigation system at RAPA Compound (Thimphu)			8.50	3.30	RGoB
	Total	**67.80**	**1223.00**	**2574.83**	**218.3 85**	

Figure 26 Works on Yabrang -Saling Irrigation system (top) & Intake structure (left) and control structure at Tharay Khola irrigation site (bottom)

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