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Improved Packages of Practices for High Altitude Rice Cultivation in Bhutan

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1.0 Background

In Bhutan rice is cultivated in three different ecosystems. These are irrigated, rainfed and upland ecosystems. Depending on altitude and rainfall, rice cultivation is categorized into five different agro-ecological zones (AEZ) which are : Warm Temperate Zone (WT) in the altitude range of 1800-2600 meters above seas level (m asl) or the **High Altitude rice** production areas; the Dry Sub-tropical Zone (DST) in the altitude range of 1200-1800 m asl; the Humid Subtropical Zone (HST) in the altitude range of 600-1200 m asl and both DST and HST are referred to as the mid altitude rice production areas; and the Wet Subtropical Zone (WST) in the altitude range of less than 600 m asl and referred to as the low altitude rice production areas. It is estimated that approximately 20% of the total national rice area falls under the Warm Temperate production zone or the high altitude rice growing areas. The high altitude rice growing areas is of special significance due to its unique climate requirements and other associated factors that influence rice production. The entire high altitude rice growing areas are categorized under the irrigated rice ecosystem.

The high altitude rice growing areas have a very short growing season, low temperature during nursery and maturity, much higher availability of irrigation water as compared to other rice growing areas, good soil fertility, land stability and a very low pest and disease pressure. The average rice yields are much higher in this zone as compared to the other rice production zones.

The Dzongkhags that fall under the high altitude rice production zones are Thimphu, Paro, Bumthang, Gasa and parts of Punakha, Wangduephodrang, Trongsa, Chhukha, Tsirang, Dagana, Lhuentse, Trashigang and Trashiyangtse. The highest altitude where rice is grown is about 2800 m above sea level in Bumthang (NBC, 2015).

During the rice crop season the WT zone has a low-high-low temperature pattern similar to that in Japan, Northern China and Korea. Low temperature is a major constraint at early growth stage and at reproductive and ripening stages. The climatic conditions of the WT zone allow only one crop of rice in a year. Day temperatures during the growing season are generally not a major constraint. However, minimum temperature of below 15^{o}C combined with low water temperature at seedling and tillering stages can cause cold injury to the rice crop. Rainfall in this zone is rather low, irrigation system is well developed and hence rice is grown as irrigated crop. Small springs and the main rivers are the sources of irrigation. River water remains cold throughout the year since it originates from the snow-clad higher mountains.

Soils in the high altitude rice growing areas are comparatively fertile in comparison to the other AEZs due to low rainfall and farmer’s regular practice of using farm yard manure with abundant leaf litter as fro animal bedding. The average rice yield in 2022 of Bumthang, Paro, Punakha, Thimphu and Wangdue Dzongkhags which represent the high altitude rice growing areas was 2.2 t acre^{-1} (National Statistical Bureau, (NSB) 2023).

Recognizing the special climatic conditions of the high altitude rice growing areas and need for specific rice production technologies, the high altitude rice research program was initiated in

1996. The immediate need to start the current ongoing high altitude research emanated from the severe impact of rice blast epidemic of 1995.

The high altitude rice research program was started in 1996 in a leased land at Geney Gewog under Thimphu Dzoongkhag by then Renewable Natural Resource Research and Development Center (RNR RDC), Yusipang (now National Center for Organic Agriculture) with the technical support of RNR RDC Bajo (now Agriculture Research and Development Center) . It was started first by identifying a rice blast hot spot site where promising materials generated through the shuttle rice breeding program between IRRI and RNR RDC Bajo could be evaluated for tolerance to blast, yield and other relevant agronomic traits. To start the program, about 2 acres of farmers land was leased at Gaynekha (2200 m asl), under Geney Geog in Thimphu Dzongkhag for a period of five years. The site was considered to be a hot spot for blast disease as blast occurred naturally and at a very epidemic scale.

In 2001, the research site was shifted to Khasdrapchu, Mewang Gewog, Thimphu Dzongkhag after leasing out 2.5 acres of farmer's field. The high altitude rice research continued there until 2015.

From 2011, NCOA Yusipang was directed by DoA to initiate rice cultivation in the fallow wetland behind Tendrilthang, Tashichhodzong, Thimphu. The rice cultivation area behind Tendrilthang kept expanding and it was difficult for the Field Crops Program of National Center for Organic Agriculture (NCOA) to manage rice cultivation at Khasadrapchu and at Tendrilthang.

In 2016, the leased land at Khasadrapchu, Mewang Gewog, and Thimphu was handed back to farmers and high altitude rice activities were shifted to the rice area behind Tendrilthang, Tashichhodzong. However, in the same year, the MoAF decided to hand over the entire rice fields behind Tendrilthang to FMCL. The area was immediately taken over by Farm Machinery Corporation Limited (FMCL) during 2016 rice harvest.

In 2017, high altitude rice research was still felt necessary and hence NCOA Yusipang sought approval of DoA and leased fallow land through FMCL in Tshento Gewog, Paro where the current high altitude rice research is ongoing. Initially 2.84 acres was leased which has been reduced to 2.05 acres in 2023 to minimize the cost. The initial lease amount with FMCL was Nu. 76,000.00 (Seventy Six Thousand only) while the new lease amount with Taktsang Goenpa is Nu. 35,000.00 (Thirty Five Thousand only). The present leased land belongs to Taktsang Monastery.

2.0 Major Production Constraints

Before making any technical recommendations it is important to understand the key production constraints of the high altitude rice growing areas. The key production constraints of the high altitude rice growing areas are briefly discussed below.

i. Cold Temperature

Injury due to cold temperature at nursery, early vegetative and maturity stages are very critical in the high altitude rice growing areas. Cold temperature affects rice yield by directly affecting the physiological processes involved in grain formatio. In general low temperatures cause the rice plant to suffer from poor and slow vegetative growth, spikelet sterility, delayed heading and poor grain filling. The critical temperature for germination is 10°C and for the reproductive stage, it is 17°C. Different rice varieties have different level of tolerance to cold temperature and it is very important to select cold tolerant and early maturing varieties. Planting of improved cold tolerant rice varieties reduces the crop loss from cold injury.

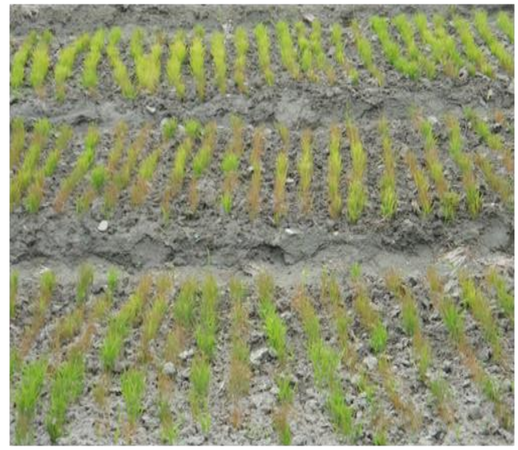

Fig. 1 Cold injury at nursery (Khasadrapchu 2011)

ii. Yellowing of Leaves in the vegetative stages

Severe yellowing of leaves is observed particularly in the improved variety *Khangma Maap* during the vegetative stages. The main symptoms observed are yellowing of the older leaves that give a burnt appearance of the whole rice field. The yellowing symptoms are similar to that of some plant nutrients deficiencies. The early tillers dry, rot and drop off after yellowing**.** As the crop matures, yellowing disappears. The symptom appears at active tillering to booting stage. This problem was reported first in 1997 from the farmer's field in Paro. The yellowing normally begins 25 –30 days after transplanting. It is inferred that yellowing is the effect of nutrient stress that usually occurs at the early crop establishment phase (immediately after transplanting), caused by the low water temperature (<17 ^{0}C). Khangma Maap is an introduced which was selected exclusively for cold tolerance at flowering rather than at seedling stages. Khangma Maap is less tolerant to cold at early growth stages. It is inferred that yellowing is mainly a factor exacerbated by cold water temperature. The rice plant normally tends to recover and become normal at flowering and the impact on yield due to yellowing is minimum. Proper management of irrigation water through intermittent irrigation as compared to continuous flow helps to reduce the extent of yellowing in rice variety Khangma Maap.

iii. Rice Blast

Rice blast caused by *Pyricularia grisea* was first reported in the country in 1984 in the Wet Subtropical rice production zone. Surprisingly, this disease was reported in epidemic scale in the high altitude rice growing areas. It is now one of the most economically important diseases of rice in WT zone. A susceptible rice variety and different environmental factors favour the development of the disease. The environmental factors responsible are: high level of nitrogen in the soil, high relative humidity, long dew period, and periods of light rainfall with low to moderate temperature and long overcast of sky.

The distinct symptoms of the disease are;

Leaf blast – Elliptical spots or lesions with more or less pointed ends, with brown border and grey centre occur on the leaves

Node blast – Nodes turn blackish and break easily

Neck blast- Lesions occur on the neck of the panicles and panicle neck turns black and breaks easily. When neck blast attacks early, the whole panicle will have empty grains.

Panicle blast- Lesions occur on primary and secondary branches of the panicle.

Planting of improved blast tolerant rice varieties is the most sustainable means to manage the incidence of rice blast.

iv. **Army Worm** *(Pseudaletia separate or Mythimna seperata)*

Armyworms are caterpillars that attack the whole rice plants. Severe outbreak of army worm is a serious concern of rice farmers of the high altitude rice growing areas. Armyworm feeds on rice by cutting off leaves and young seedlings at the plant's base. Sporadically the caterpillar appears in big swarms, causing heavy losses, especially when a dry spell (30-40 days) follows prolonged rainy days in the spring. Caterpillar voraciously feed on the foliage and moves from one field to another.

According to the National Plant Protection Center (NPPC) , under severe incidence,
Chemical spray may be necessary as a last resort during an outbreak.

- Spray Chlorantraniliprole 18.5% SC (0.3 ml per liter of water) or Emamectin benzoate 5% SG (0.2 gram per liter of water)
- Since the armyworm usually feeds at night, the best time to spray is late in the day.
- To prevent the caterpillars from moving to another field, application of a 15-metre border spray around the non-infested field is important..

v. Weed - Schochum *(Potamogeton distinctus)*

Schochum *(Potamogeton distinctus)* is the most noxious weed of the high altitude rice growing areas. It has been estimated that Schochum infestation can reduce rice production by over 37%.

2.0 Objectives

The high altitude rice research program was started as a medium to long term strategy to develop **improved rice varieties** with resistance to rice blast and with suitable adaptation to the climatic conditions of the of the high altitude rice growing areas. The primary objectives of the high altitude rice research program are:

i. To develop and screen of improved rice materials that have specific resistance to rice blast and other diseases

ii. To develop, evaluates and identify materials having good cold tolerance, easy threshability, good grain and straw yields, desired cooking and eating characteristics
iii. Initiate rapid seed multiplication and dissemination of blast tolerant varieties to the affected farmers of the high altitude rice growing areas

4.0 Technical Recommendations

As an output of the high altitude rice research program, improved rice production and management technologies are recommended from nursery to harvesting.

4.1 Nursery Establishment and Management

There are different methods by which rice seedlings can be produced. The best method for specific location is one which is acceptable to the farmers and one that guarantees good quality rice seedlings available for transplanting at the right time. Farmers in Bhutan, particularly in the high altitude rice growing areas commonly practice drybed method where seeds are sown onto dry fields without preparing seed beds and irrigation. Seed bed duration is long, upto 90 days. The long seedling duration allows the seedlings to be hardy against cold temperature. Wastage of land and seeds, weeds and blast are common problems in this method.

The improved nursery raising methods are:

4.1.1 Semi-dry bed method

This method is recommended for the high altitude areas where water shortages are a major constraint for raising rice nursery. The main advantages of the semi dry bed method are that it requires less seed, small area and nursery management is easy. In this method nursery can be raised in the rice terrace itself. Labour requirement is high only for preparation of beds but as the management is easy the overall labour required is less compared to the farmer’s traditional method. This method is good for areas where pressure from weeds like Shochum (*Potamogeton distinctus)* is common and in areas where low temperature is a problem at the seedling stages. To raise nursery in the semi- dry bed method:

- Prepare a well-leveled field with fine pulverized soil.
- Apply well-rotten FYM and thoroughly mix with the soil. About 3 kg will be enough for a seedbed of 1 m x 3 m.
- Make raised beds 10-13 cm high, 1 m wide, and of any convenient length.
- Broadcast treated dry seeds uniformly on the seedbeds. One "drey" or 1.2 kg seed will be sufficient for an area 1 m x 6 m.
- Cover the seeds using a thin layer of fine soil mixed with well-decomposed FYM.
- Irrigate the bed immediately after sowing. The beds should be just soaked. Never flood.
- Check the moisture of the seedbed and irrigate when necessary.
- The seedlings will be ready to transplant 40-50 days after sowing, depending on altitude and temperature.

4.1.2 Tray nursery for Mechanized Transplanting

This method is used for the mechanical transplanting when a paddy transplanter is used for transplanting the seedlings. Seeds are sown in plastic trays of size 60 x 30 x 3cm. The trays are filled with fine red soil. About 150 – 200 grams (gm) of seed is sown per tray. After seeding the seeds are covered with 1 cm thick soil layer. The trays are then placed on well leveled floor inside in the plastic house. Regular irrigation is given to the trays and the seedlings are ready for transplanting at 3.5 to 5^{th} leaf stage in about 30-40 days. The seedling can be taken out as a mat and fed to the transplanter for transplanting. This method is becoming popular in Paro valley where farm mechanization is promoted by the Agriculture Machinery Center (AMC).

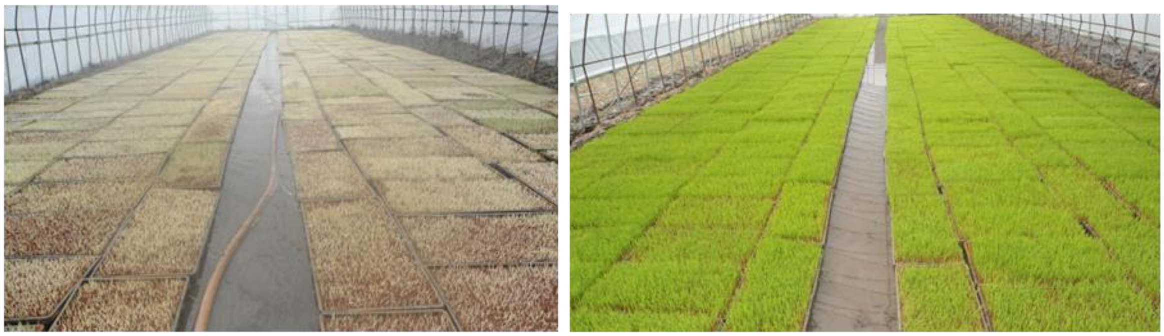

Fig. 2 Tray nursery (Khasadrapchu 2012)

4.2 Seed Rate

Depending on the method used to raise seedlings, an average seed rate of 20-25 kg per acre is recommended.

4.3 Seed Treatment

In order to ensure good germination seed treatment is essential. The seed treatment can be done in a simple manner.

- Put the required seed in a bucket of water. The good seed will sink while the unfilled and poor quality seeds will float. Collect and throw away the floating seeds. Drain out water and dry the seeds which have sunk for sowing in nursery (Fig.3).

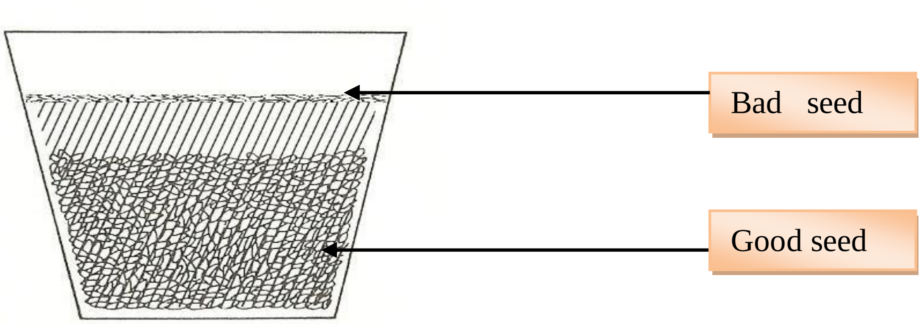

Fig. 3 Method of seed treatment

4.4 Sowing Time for Nursery

The time of nursery establishment for high altitude rice production zone is very critical because of the short growing season and cold temperature during the nursery. Farmers normally sow the nurseries right after the Bhutanese New year (Losar) in the first week of the Bhutanese First Month. The recommended nursery sowing time is from late February to the second week of 15th March. In case of the tray nursery, it can be established in the first week of April

4.5 Transplanting

In the high altitude rice growing areas, rice is grown entirely under irrigated ecosystem. Transplanting can be done manually or using a mechanical rice transplanter. In Bhutan, transplanting is largely done manually, but many farmers in Paro, Wangdue and Punkaha have now started using rice transplanters. The Farm Machinery Corporation Limited (FMCL) provided hiring services of rice transplanters for mechanized transplanting. This has eased the issue of farm labour shortage during the transplanting time.

4.5.1 Methods of Transplanting

Rice can be transplanted at random or in straight rows or lines. In our country, random transplanting is the most common method, which requires less labour compared to planting in lines.

Traditional or random method of transplanting can be adopted if the weed pressure is expected to be low, if herbicides such as Butachlor are intended to be used for weed control and, where rice terraces are narrow and small. Avoid wide spacing in random transplanting. A plant density of 25-35 hills per square meters is optimum.

- Line planting is recommended where the aim is to control weeds using a rotary weeder. Line planting also enhances the attainment of an optimum plant population and facilitates weeding and other operations.
- In line planting, use ropes, guides or markers to attain straight rows. Plant seedlings on spots indicated by ropes or markers.
- Maintain row spacing of 20 cm and plant to plant spacing of 15-20 cm within the rows. Transplant 2-3 seedlings per hill at a depth of 2-3 cm.
- Increase the number of seedlings per hill if transplanting is delayed or if the seedlings are old to compensate for reduced tillering.
- There is no single spacing recommended for all varieties – it will depend on the variety, soil fertility and planting season.
- If a rice transplanter is used, allow the mud to settle for a day before transplanting to avoid sinking of seedlings. Land preparation has to be thorough and seedlings need to be raised in trays.

4.6 Time of Transplanting

The time of transplanting depends on the altitude regime and also the variety. In the high altitude rice growing areas the transplanting has to be done from **mid May to early June** to avoid the damage from cold temperature at flowering and grain formation stages.

4.7 Rice Varieties

Both traditional and improved rice varieties are cultivated in the high altitude rice growing areas. However, more recently the improved varieties have become more popular. It has been estimated that over 80% of the high altitude rice growing area is planted to the improved rice varieties. The shift to improved rice varieties is mainly driven by the higher susceptibility of traditional varieties to rice blast and low productivity of traditional varieties. Traditional varieties are planted in small scale for household consumption and to meet specific household and religious needs.

4.7.1 Traditional Rice Varieties

Many popular traditional varieties used to be cultivated by the farmers in the high altitude rice growing areas in the past. Most of the traditional varieties, however, have been replaced by modern high yielding varieties. Although the traditional varieties are highly preferred for their taste, higher market price and earliness they are susceptible pests, lodging and have low yield potential. The traditional varieties are characterized high cold tolerance at the seedling stage, tall stature, long growth duration with medium to low tillering and red pericarp. Some of the popular high altitude rice varieties still in cultivation are Dumbja, Naam, Kuchum, Themja, Zhuchum, Naam, Machum and Hasey.

4.7.2 Improved Rice Varieties

A total 8 improved rice varieties are recommended for the high altitude. Of the six, two are introduced varieties while the remaining four are those developed using local rice varieties as one of the parents.

Fig. 4. Farmers assessing new high altitude rice varieties

Table 1. Improved rice varieties recommended for high altitude rice growing areas

Variety	Parents	Year released	Yield Potential t/ha	Main Traits
Khangma Maap (Chumro)	-	1999	4-5	Plant height 115-120 cm. Maturity 170-175 days, Blast tolerant, high yielding, tall, high straw yield, red grain, Released by ARDC Wengkhar.
Yusi Ray Maap1	Suweon 359//IR41996-118-2-13/Thimphu Maap	2002	5-6.5	Plant height 118 cm, maturity 170-190 days, Blast tolerant, high yielding, No lodging, bold grain with red pericarp, less shattering
Yusi Ray Kaap1	YR3825-11-3-2-1/YR3825-11-3-2-1/Barket	2002	5-6.5	Plant height 118 cm, maturity 170-190 days, Blast tolerant, high yielding, no lodging, bold grain with white pericarp, less shattering
Jakar Ray Naap	-	2006	4-5	Early, susceptible to blast under high nitrogen level and high disease pressure, red grain, easy threashability. Released by then ARDC Jakar.
Yusi Raykaap 2	Akiyutaka/Naam	2010	5-6	Plant height 97 cm, maturity 130-140 days, Blast tolerant, high yielding, easy threashability, bold grain white pericarp, no lodging
Yusi Raymaap 2	Akiyutaka/Rey Maap	2010	5-6	Plant height 99 cm, maturity 135-140 days, Blast tolerant, high yielding, bold grain with red pericarp, easy treatability, no lodging
Yusi Raykaap 3	YPS-7	2018	3.4-3.5	Has good field tolerances to rice blast disease, Shattering loss is very minimum, Widely accepted by the farmers in Paro, Good market acceptance
Yusiray Kathramathra	PP4-38-4	2018	3.78-4.0	High yield, tolerant to rice blast, good adaptability
Yusi Raymaap 3	Bulk 20 (YPK-YB20)	2023	3.4-3.5	High yield, rice blast tolerant, lodging resistant

4.8 Weed Management

Weed infestation is the most widely reported biological constraint that reduces the rice yields. Weed competes with the rice crop for water and nutrients and can reduces yield to over 50% in transplanted crop if it is not managed adequately. In the WT zone, Shochum (*Potamogeton distinctus)* is the most noxious weed. Other broadleaf and grassy weeds are also present but can be managed with herbicides. Weeding is normally labour intensive and availability of farm labour is a key constraint. The extensive use of herbicides is undesirable environmentally and they are expensive. It is therefore very necessary to adopt integrated weed control methods that comprise good land preparation, proper water management, and use of weed-free seedbeds and seeds.

To ensure good weed management it is important to adopt the following recommendations:

- In order to manage Schochum carry out intensive hand weeding 3-4 times thoroughly at 2, 4 and 6 weeks after transplanting by removing and destroying the weeded Shochum biomass.
- Pull out the roots and dispose the weeds in a pit away from the field.
- To minimize Shochum problem, adopt cultural methods like increased tillage, deep ploughing, and restricting the physical movement of plant parts from one field to another.
- In order to control other broad leaf and grassy weeds aapply granular herbicide Butachlor (Punch) at the rate of 10-15 Kg acre $^{-1}$ after 2-3 days of transplanting to get good control of weeds. Apply Butachlor only if *Potamogeton* (Shochum) is absent.
- The National Plant Protection Center (NPPC) recommends the use Ethoxysulfuron 15% WDG (Sunrice), a post-emergent broad spectrum selective herbicide effective against sedges and broad-leaf weeds including *Potamogeton distinctus* (Shochum) in transplanted rice. Formulated 50g (1 bottle) Sunrice should be diluted in 250 liters of water OR 1g in 5 liters of water. It should be well dissolved in the water before application. Sunrice herbicide should be applied within 10 to 15 days after transplantation (DAT) of paddy or when weeds, particularly *Potamogeton distinctus* (Shochum) are at 2-3 leaf growth stage.

4.9 Manure and Fertilizer

Farmers routinely apply Farm Yard Manure (FYM) to rice field. The rate of application varies widely from 5 to 12 t ha^{-1}. FYM contributes significantly to crop nutrition and soil condition. It is desirable to encourage the use of FYM. Our recommendation is to apply about 5-8 t ha^{-1} FYM before field preparation. For obtaining optimum yield application of inorganic fertilizer is recommended. Application of 111:17:102 NPK Kg ha^{-1} is recommended for modern high yielding varieties. Half the N and, all the P should be applied as the basal dose. The remaining N should be top dressed 35-40 days after transplanting. For local varieties, limit N to 50 Kg ha^{-1} to prevent lodging.

4.10 Water Management

After transplanting the water level should be kept low for 4-7 days until the seedlings recovers. Water level should then be increased as the crop grows ensuring adequate water from tillering to flowering. If the supply of water is limited, continuous flooding is not possible. In this case irrigate at short intervals but do not let the field become excessively dry and crack. Flowering is the most critical stage when rice should not be exposed to moisture stress. Drain out water from the field 10-15 days before harvest to enhance ripening.

4.11 Harvesting

Under normal conditions harvesting begins from the first week of October. Harvest the crop when at least 85% of the upper portion of panicles turns straw colour. Some leaves and stems may still be green at grain maturity, particularly for improved varieties.

5.0 Conclusion

The high altitude rice program was initiated in the wake of the 1995 rice blast epidemic that severely affected the high altitude rice goring areas in the country. This research program has evaluated over 5000 different germplasm introduced from different sources. Through this research six rice blast resistant varieties have been released which have been widely adopted by farmers. Additional two varieties namely Khangmaap was released by ARDC Wengkhar and Jakarray Naap by then ARDC Jakar. The rapid seed increase and dissemination of these varieties has been the most sustainable strategy to contain the rice blast. It has been estimated that over 80% of the high altitude rice growing areas is planted to the improved rice varieties. This research program is currently ongoing and will be reviewed and realigned to address the climate change exacerbated abiotic and biotic stresses.

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