ADB

Technical Assistance Report

Project Number: 47163
Research and Development Technical Assistance (RDTA)
September 2013

Development and Dissemination of Climate-Resilient Rice Varieties for Water-Short Areas of South Asia and Southeast Asia

(Cofinanced by the Climate Change Fund and the Government of Finland)

Asian Development Bank

ABBREVIATIONS

ADB	–	Asian Development Bank
AWD	–	alternate wetting and drying
IRRI	–	International Rice Research Institute
TA	–	technical assistance

TECHNICAL ASSISTANCE CLASSIFICATION

Type	–	Research and development technical assistance (RDTA)
Targeting classification	–	General intervention
Sector (subsector)	–	Agriculture and natural resources (agricultural production and markets)
Theme (subthemes)	–	**Economic growth** (knowledge, science, and technological capacities); environmental sustainability (natural resources conservation); regional cooperation and integration (other regional public goods)
Climate change	–	Climate change adaptation
Location (impact)	–	Rural (high), national (medium), regional (medium)
Partnerships	–	Climate Change Fund, Government of Finland, International Rice Research Institute

NOTE

In this report, "$" refers to US dollars.

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I. INTRODUCTION

1. This regional research and development technical assistance (TA) is requested by national rice research institutions following the successful completion of the regional TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia,[1] primarily to implement large-scale dissemination of promising breeding lines developed under the same TA and to continue developing breeding lines tolerant to water stress. The present TA will cover water-short and seasonally water-scarce countries in South Asia (Bangladesh, India, and Nepal), with extension to Southeast Asia (Cambodia and the Lao People's Democratic Republic) given similar problems in this region, through further adaptation research, variety trials, and knowledge transfer of the technologies developed under the earlier TA. Respective governments concur with the present TA's impact, outcome, outputs, cost, implementation and financing arrangements, and terms of reference.[2] The TA is consistent with the medium-term corporate strategic priorities for research of the Asian Development Bank (ADB) on (i) mitigating climate change, (ii) responding to increasing commodity prices, and (iii) promoting inclusive growth.[3]

II. ISSUES

2. In Asia and the Pacific, 90% of the total diverted freshwater is used to irrigate agriculture, and more than 50% of this is used to irrigate rice. The growing scarcity of water worldwide has started to influence conventional irrigated rice production. By 2025, physical water scarcity will affect an estimated 15 million hectares.[4] Climate change estimates predict the irrigation water deficit and the intensity and frequency of water shortage to deteriorate further. The Intergovernmental Panel on Climate Change estimates that about 1.2 billion people could face freshwater shortages by 2020 and that crop yields in some parts of the region could drop by as much as 30% by 2050.[5] This will impact both irrigated and rain-fed agriculture. The interannual rainfall variability, including the concentration of rain over fewer days in a year and in different locations, will further impair surface irrigation systems. Droughts as a result of water shortage will occur with new and varied intensities.

3. The increasing water scarcity highlights the need to improve the water productivity of rice and to reduce its susceptibility to water stress to ensure adequate food for future generations. The International Rice Research Institute (IRRI), through its research on water-saving technologies, developed the alternate wetting and drying (AWD) technology for high-yielding transplanted rice. Testing at IRRI and field experience in Bangladesh and India have shown that the AWD system leads to savings of at least 15%–20% water compared with transplanted flooded rice, without any decline in yields. Technologies that require further development include aerobic rice as a prominent water-saving technology for moderate yield capacity, direct-seeded situations, and new varieties that are more tolerant of water-stress events. Aerobic rice trials using direct seeding have demonstrated water savings of 30%–35%. In addition, aerobic rice is a labor-saving technology, and can also be carried more efficiently

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1 ADB. 2006. *Technical Assistance for Development and Dissemination of Water-Saving Rice Technologies in South Asia.* Manila.

2 The TA design and monitoring framework is in Appendix 1.

3 The TA first appeared in the business opportunities section of ADB's website on 27 June 2013.

4 T.P. Tuong and B.A.M. Bouman. 2003. *Rice Production in Water-Scarce Environments.* In J.W. Kijne, R. Barker and D. Molden, eds. *Water productivity in agriculture: Limits and opportunities for improvement*. Wallingford: CABI Publishing. pp. 53–67.

5 R.V. Cruz et al. 2007. Asia. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry et al, eds. Cambridge, UK: Cambridge University Press. pp. 469–506.

with tractor-driven seeding implements. The frequency of water-stress events during the rice-growing period are becoming more common, and varieties that suffer less yield loss from these events need to be further developed.

4. From January 2006 to August 2010, ADB supported TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia. In collaboration with IRRI and national rice research organizations in Bangladesh, India, Nepal, and Pakistan, that TA (i) disseminated two principal water-saving rice technologies—AWD and aerobic production—from IRRI to participating countries, (ii) developed new generation of rice varieties suitable for these water-saving technologies, (iii) disseminated promising breeding lines to national systems through participatory varietal selection processes, and (iv) identified cropping patterns and weed control measures for sustainable rice production in aerobic situation. Lessons learned include the need to (i) increase resources for expanded variety trials in participating countries, and (ii) continue the developmental work. The present TA responds to both issues.

5. Government rice research agencies evaluated the breeding lines with the participation of local farmers in each country. Both AWD and aerobic technologies have generated positive results in farmers' fields—the identified breeding lines yield 10%–30% more despite less water. Therefore, the governments have requested ADB support for large-scale seed multiplication; evaluation and dissemination of second-generation, climate-adapted water-saving rice varieties; and development and initial dissemination of new, third-generation aerobic and AWD varieties, as well as impact assessments.[6] These activities are essential to achieving food security in the face of climate-change-induced water shortage in rice production areas.

6. The TA aligns with ADB's Strategy 2020, where the environment and climate change are a core area of operation.[7] The TA is consistent with climate change impact on water and food security; knowledge solutions; and inclusive, environmentally sustainable development, as prioritized in the country partnership strategies for each participating country. The TA is also consistent with ADB's Operational Plan for Sustainable Food Security in Asia and the Pacific, which calls for broader support of agriculture research, and contributes to two key pillars of the operational plan—enhancing agriculture productivity and improving resilience to climate change and price volatility[8]—and to the Water Operational Plan, 2011–2020, which emphasizes expanding and deepening knowledge and dissemination of technology advances, and minimizing footprints through supporting water saving and conservation measures.[9]

7. The outcome of the TA can be leveraged for inclusion in food-security-related investment projects. Adoption of water-saving rice varieties can be a project component of an investment project on food security, which often requires comprehensive measures in dealing

[6] The first-generation varieties were developed by crossing lowland varieties with upland varieties, combining high yield potential of lowland lines with weed competitiveness, drought tolerance of upland lines, and resistance against blast and bacterial leaf blight. The first-generation varieties lack improvements in grain quality. The second-generation varieties developed in the TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia add into the first generation with medium-slender grain and good grain quality traits. However, the second-generation varieties lack tolerance to nematodes with reduced nutrient uptake. The third-generation aerobic rice varieties will combine the second generation with increased nutrient uptake under an aerobic situation, and tolerance to nematodes. By incorporating increased nutrient uptake and nematode tolerance under an aerobic situation through a marker-assisted breeding approach, the third-generation varieties shall show greater yield and better adaptation to aerobic situations than second-generation varieties.

[7] ADB. 2008. *Strategy 2020: The Long-Term Strategic Framework of the Asian Development Bank, 2008–2020.* Manila.

[8] ADB. 2010. *Operational Plan for Sustainable Food Security in Asia and the Pacific.* Manila.

[9] ADB. 2011. *Water Operational Plan, 2011–2020*. Manila.

with the issue of food supply amid climate change. Capacity development and effective adoption of rice varieties with private sector involvement, and establishing institutional infrastructure to facilitate take-up are also potential follow-up investment opportunities to sustain the development and dissemination of climate-adapted rice varieties.

III. THE TECHNICAL ASSISTANCE

A. Impact and Outcome

8. The TA impact will be sustainable rice production with climate-resilient varieties in South Asia and Southeast Asia. The TA outcome will be increased rice yield and water efficiency in water-short irrigated and drought-prone rain-fed areas.

B. Methodology and Key Activities

9. The outputs of the TA will be: (i) high-yielding rice varieties suitable for water-short climates developed and disseminated; and (ii) site-specific crop management packages for aerobic cultivation in water-short areas developed and disseminated.

10. For output 1, the TA will multiply the second-generation, water-saving varieties (two aerobic and two AWD) identified in the TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia, distribute seeds to 5,000 farmers in each country, and advise farmers in each country on how to grow and cultivate the climate-adapted aerobic and AWD varieties. The TA will further develop third-generation, nematode-resistant and water-saving varieties by crossing nematode-tolerant lines with a high-yield line, and high-yield aerobic rice with a high-yield lowland line grown in shallow lowland ecosystems. The breeding lines will be shared with participating countries and in the second year will be evaluated in yield trials. Promising lines from advanced yield trials will be nominated to national trials for release as new varieties.

11. For output 2, the TA will develop and disseminate site-specific fertilizer, weed, water, and soil management and mechanization techniques. Site-specific management systems with high and moderate nutrient input will be determined. Soil health and soil nutritional status under aerobic and AWD systems will be analyzed for each site. Suitable crop rotations for the aerobic system will be evaluated from long-term experiments.

12. The TA will involve both basic research at IRRI and adaptive research in collaborating national agricultural research centers and in farmers' fields. Participatory approaches will be used in validating and disseminating suitable technologies. In each participating country, the targeted breeder seed production of the improved varieties will be carried out at the participating institutions. For the production and distribution of certified seed to farmers, the TA, through the participating institution in each country, will link with seed-producing public and private agencies and nongovernment organizations to produce the target 1,000 tons of quality seed.

13. Knowledge sharing and capacity building are integral parts of the two outputs. IRRI and the participating national institutes will disseminate knowledge and techniques via (i) climate-adapted varieties and management practice packages to about 5,000 farmers in water-short sites in each of the five participating countries; (ii) a book on recent advances in water-saving rice technologies; (iii) a manual, with translation to local languages, of practices for water-saving technologies based on the selected AWD and aerobic varieties; and (iv) publication of at least two scientific papers in refereed journals. Two research assistants at PhD candidate level, one

each from South Asia and Southeast Asia participating countries, will be advised by IRRI to conduct research on how to further improve yields under aerobic water-saving conditions and develop third-generation aerobic rice varieties. In addition, a series of training courses on the development and use of water-saving technologies for rice production will be organized among national scientists and extension workers.

14. The TA has a low risk profile, with demonstrated success built on the achievements of the ADB-funded TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia. IRRI, the proposed research institute to be hired as a firm, has world-class research facilities and capacity, and a long record of collaboration with the cooperating country research institutions responsible for in-country varietal assessments and seed multiplication. Multiple testing sites in each country will mitigate the potential risk that wet seasons may prevent water-shortage-adaptable traits from being exhibited.

C. Cost and Financing

15. The TA is estimated to cost $1,370,000, of which (i) $750,000 will be financed on a grant basis by the Climate Change Fund;[10] and (ii) $620,000 will be financed on a grant basis by the Government of Finland, to be administered by ADB. The cost estimates and financing plan are in Appendix 2.

D. Implementation Arrangements

16. The TA will be implemented over 3 years (January 2014–December 2016). ADB will be the executing agency.

17. The TA proceeds will be disbursed in accordance with ADB's *Technical Assistance Disbursement Handbook* (2010, as amended from time to time). All procurement will be carried out in accordance with ADB's Procurement Guidelines (2013, as amended from time to time), and consultants will be recruited in line with ADB's Guidelines on the Use of Consultants (2013, as amended from time to time).

18. The TA requires 121.2 person-months of international consulting and 120 person-months of national consulting services. The consultant team will comprise (i) an international senior scientist to act as team leader; (ii) an international rice breeder to help manage the breeding and screening program; (iii) two international plant breeders to assist country-specific seed multiplication, dissemination, varietal evaluation and survey, and impact assessment; and (iv) two international research assistants who are PhD students; and (v) five national research technicians. The outline terms of reference for consultants are in Appendix 3.

19. ADB will engage IRRI to provide the consulting services using single-source selection. This is justified because (i) IRRI has a long track record as an internationally recognized institute for rice-related research, training, and knowledge transfer and for developing new rice varieties and rice crop management techniques that help rice farmers improve the yield and quality of their rice in an environmentally sustainable way; (ii) the TA is a follow-on to the TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia under which IRRI has successfully made scientific progress and developed intellectual knowledge that is publicly available; and (iii) as an international center of excellence on rice, IRRI has exceptional worth and is the only one qualified with experience for the assignment. IRRI will

[10] Established by ADB.

enter into subcontracts with collaborating national research centers for in-country research, demonstration, dissemination, and training. The value of ADB's contract with IRRI is $1,370,000. IRRI will be paid on a milestone payment basis.

20. IRRI will hold an inception workshop within 2 months of the notice to proceed to provide a detailed work plan and milestones for each output. IRRI will submit the following reports to ADB: (i) an inception report within 3 months of mobilization; (ii) semiannual progress reports; (iii) a draft final report by October 2016; and (iv) a final report acceptable to ADB by December 2016. For output 2, IRRI will also need to (i) compile, publish, and disseminate a book on latest advances in water-saving rice technologies by December 2014; and (ii) produce and disseminate a manual for site-specific fertilizer, weed, and water management and mechanization techniques by December 2014.

21. IRRI will provide office accommodation, transport, and other support services in the Philippines. Collaborating institutions in each of the participating countries will provide office accommodation and facilities, field facilities for seed multiplication and dissemination, and necessary facilities, room and equipment for training, and technology dissemination.

22. The TA will ensure availability of climate-adapted rice varieties through collaboration with national and provincial seed multiplication agencies, public and private sector institutes, and nongovernment organizations for large-scale seed production and distribution. Varieties developed under the TA shall be available for cultivation to all farmers in beneficiary countries and can be shared with different research institutions in different countries after the signing of the IRRI standard material transfer agreement.

23. Monitoring and evaluation are integral to the design and implementation plan of the TA. A TA monitoring system will be established with baseline data by country and production system. Parameters including water saving,[11] yield, pest and disease tolerance, fertilizer efficiency, and farmer and consumer preference will be evaluated under scientific analysis as well as through farmer participative evaluation of on-field trials. Impact analysis and a TA completion report will be prepared in the final year of the TA. [12]

24. Good practices and lessons learned will be prepared and disseminated and, along with the new technology and varieties, will be a major contribution to the regional knowledge bank of ADB, IRRI, and the country research institutions.

IV. THE PRESIDENT'S DECISION

25. The President, acting under the authority delegated by the Board, has approved (i) ADB administering a portion of technical assistance not exceeding the equivalent of $620,000 to be financed on a grant basis by the Government of Finland, and (ii) ADB providing the balance not exceeding the equivalent of $750,000 on a grant basis, for the Development and Dissemination of Climate-Resilient Rice Varieties for Water-Short Areas of South Asia and Southeast Asia, and hereby reports this action to the Board.

[11] Scientists will measure the amount of water received by each experiment through rainfall by rain gauge, and additional water provided through irrigation by water meter, at the mouth of the field from beginning of sowing of each experiment under conventional transplanting, AWD, and aerobic situations to quantify the amount of water saving achieved in AWD and aerobic rice as compared to water provided in the conventional system.

[12] A pooled regression-based approach on data collected from adopting and nonadopting farmers can be used to evaluate the benefits of the TA.

DESIGN AND MONITORING FRAMEWORK

Design Summary	Performance Targets and Indicators with Baselines	Data Sources and Reporting Mechanisms	Assumptions and Risks
Impact Sustainable rice production with climate-resilient varieties in South Asia and Southeast Asia	By 2020, 10% of farmers in each target country have adopted varietal and production technologies developed and promoted under the TA (baseline: 1 - 2% in 2013)	Records and reports from water and agriculture ministries in each participating country	**Assumption** Participating country governments release varieties in a timely manner and target likely water-scarce areas. **Risk** Dissemination is restricted by political instability in rice areas prone to water shortage.
Outcome Increased rice yield and water efficiency in water-short irrigated and drought-prone rain-fed areas	Average rice yield in the participating countries increased by 10% by 2016 (baseline: 6.0-6.5 tons/hectare in AWD and 5.0 tons/hectare under aerobic production in 2013) Average water use reduced by 10% under AWD and 20% under aerobic production by 2016 (baseline: 1,200-1,500 millimeters in 2013)	Records from agricultural ministry in each participating country Records from agricultural ministry in each participating country	**Risk** Wet seasons prevent water-shortage-adaptable traits from being exhibited
Outputs 1. High-yielding varieties suitable for water-short climates developed and disseminated	1,000 tons of second-generation seeds, being two aerobic and two AWD varieties, produced by breeder in each country by 2016 (baseline: 10 to 100 tons of base seed in 2012) Seeds distributed to 5,000 farmers in each country by 2016 Third-generation, nematode-tolerant aerobic and AWD varieties developed with a yield increase of 10% over second- generation varieties in replicated trials, and disseminated to partner countries by 2016 (baseline: 5.5-6.0 tons/hectare in 2013)	Reports of rice research institutes in each participating country Reports of rice research institutes in each participating country Reports of IRRI and rice research institutes in each participating country	**Assumptions** Participating institutions undertake successful seed multiplication and distribution.
2. Site-specific crop management packages for aerobic cultivation in water-short areas developed and disseminated	Site-specific fertilizer, weed, water, and soil management and mechanization techniques developed and disseminated by 2015 Book on recent advances in water-saving rice technologies published by December 2014 A manual detailing proven sustainable aerobic rice practices produced by December 2014	Reports of rice research institutes in each participating country ADB and IRRI news release and websites Reports of rice research institutes in each participating country	

Design Summary	Performance Targets and Indicators with Baselines	Data Sources and Reporting Mechanisms	Assumptions and Risks
	At least two scientific papers on TA results submitted for publication in refereed journals by June 2016	Journal editor's confirmation letters	

Activities with Milestones

1. High-yielding varieties suitable for water-short climates developed and disseminated

1.1 Conclude contract negotiations with IRRI (by December 2013)
1.2 Establish project monitoring system (by March 2014)
1.3 Determine baseline data by country and production system (by June 2014)
1.4 Second-generation, water-efficient varieties identified in the TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia are multiplied and cultivated by farmers
  1.4.1 Multiply base seed of second-generation aerobic and AWD varieties that have been either released or promoted to be released in each country and distribute the seed to 5,000 farmers in each country (by May 2015)
  1.4.2 Five thousand farmers in each country grow climate-adapted aerobic and AWD varieties (by May 2015)
1.5 Third-generation, nematode resistant and water-efficient varieties are developed and disseminated to partner organizations
  1.5.1 Develop third-generation mapping populations using nematode-tolerant lines identified in the TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia as donor, and a high-yielding line as recipient (by December 2014)
  1.5.2 Develop third-generation mapping populations using high-yielding aerobic rice line identified in the TA for the Development and Dissemination of Water-Saving Rice Technologies in South Asia as donor, and a high-yielding lowland line grown in shallow lowland area as recipient (by December 2014)
  1.5.3 Share breeding lines with national institutions (by March 2015)
  1.5.4 Evaluate promising lines in advanced yield trials, and nominate lines to national trials for release as varieties (by June 2016)

2. Site-specific crop management packages for aerobic cultivation in water-short areas developed and disseminated

2.1 Compile and publish a book on recent advances in water-saving rice technologies (by December 2014)
2.2 Determine site-specific management systems with high and moderate inputs of nutrients (by December 2014)
2.3 Analyze soil health and soil nutritional status under aerobic and AWD systems for each site (by June 2015)
2.4 Identify suitable crop rotations for an aerobic system (by June 2015)
2.5 Produce, translate (into participating countries' local language), and disseminate a farmer's manual for site-specific fertilizer, weed, soil, and water management and mechanization techniques (by December 2015)
2.6 Disseminate the book, manual, and site-specific technology to extension staff and farmers (by December 2016)

Inputs

Climate Change Fund: $750,000

Item	Amount ($)
Consultants	541,000
Training, workshop, and conferences	49,000
Surveys, studies, and research	110,000
Contingencies	50,000

Government of Finland: $620,000

Item	Amount ($)
Equipment	50,000
Field trials and demonstrations	248,000
Surveys, studies, and research	140,000
Miscellaneous administration and support costs	132,000
Contingencies	50,000

ADB = Asian Development Bank, AWD = alternate wetting and drying, IRRI = International Rice Research Institute, TA = technical assistance.
Source: Asian Development Bank estimates.

COST ESTIMATES AND FINANCING PLAN
($)

Item		Amount
A.	**Climate Change Fund**[a]	
	1. Consultants	
	a. Remuneration and per diem	
	i. International consultants	341,000
	ii. National consultants	104,000
	b. International and local travel	44,000
	c. Reports and communications	52,000
	2. Training, workshop, and conferences	49,000
	3. Surveys, studies, and research	110,000
	4. Contingencies	50,000
	Subtotal (A)	**750,000**
B.	**Government of Finland**[b]	
	1. Equipment[c]	50,000
	2. Field trials and demonstrations	248,000
	3. Surveys, studies, and research	140,000
	4. Miscellaneous administration and support costs	132,000
	5. Contingencies	50,000
	Subtotal (B)	**620,000**
	Total	**1,370,000**

[a] Established by the Asian Development Bank (ADB).
[b] Administered by ADB.
[c] Including field and lab equipment. After completion of the technical assistance, equipment will remain with the national research institutes involved in the technical assistance.

Source: Asian Development Bank estimates.

OUTLINE TERMS OF REFERENCE FOR CONSULTANTS

A. International Consultants

1. **Senior scientist** (team leader, 1.2 person-months). The senior scientist shall spend 6 person-months on an intermittent basis on the TA, with 20% of his or her time charged to the TA, and the remaining 80% financed by the International Rice Research Institute (IRRI). The senior scientist will

(i) provide overall supervision and guidance to different activities of the project;
(ii) act as focal point to interact with national partners;
(iii) act as focal point to interact with the Asian Development Bank (ADB) for reporting and project execution;
(iv) provide expertise support, guidance, and breeding materials to national partners to establish breeding programs for developing varieties for water-short conditions;
(v) organize a project implementation workshop at the start of project implementation;
(vi) organize annual project meetings in consultation with the ADB project officer; and
(vii) manage publication of a book on recent advances in water-saving rice technologies.

2. The senior scientist will be a staff of IRRI and shall be an expert in plant breeding, genetics, and biotechnology with a PhD in a relevant field.

3. **Rice breeder** (24 person-months). The rice breeder will

(i) help the team leader in all aspects of project management, including
  (a) site monitoring visits;
  (b) reporting requirements, including preparation of semiannual progress and financial reports, and preparation of final comprehensive report;
  (c) budget monitoring and fund disbursement to sites; and
  (d) coordination of training activities;
(ii) supervise selection and evaluation of alternate wetting and drying (AWD) and aerobic rice varieties at the IRRI headquarters;
(iii) supervise research at IRRI on developing third-generation aerobic rice lines that combine high water nutrient uptake ability with high grain yield, blast, bacterial leaf blight tolerance;
(iv) collaborate with IRRI water scientists in documenting water savings achievable through the use of improved germplasm;
(v) collaborate with participating national institutions on proper seed multiplication and dissemination of promising lines;
(vi) submit for publication at least two scientific papers in refereed journals summarizing research results; and
(vii) produce a manual for site-specific fertilizer, weed, water, and soil management and mechanization techniques, to be published and disseminated by 2015, and supervise translation of the manual into country languages.

4. The rice breeder should have expertise in breeding, agronomy, and crop management for water-saving systems to help manage the breeding and screening operations. With a PhD degree in a relevant field, the rice breeder will be hired within the IRRI position level of postdoctoral fellow, following a regional search targeted at scientists with experience in AWD, aerobic rice breeding, agronomy, or soil health.

5. **Plant breeders** (2 persons each for 24 person-months, total 48 person-months). The plant breeders will

(i) assist the senior scientist and the rice breeder in implementing the projects in participating countries, including
  (a) conducting seed multiplication and dissemination;
  (b) helping local teams identify target farmer groups for participatory evaluation of water-saving varieties;
  (c) training extension agents on seed multiplication;
  (d) conducting participatory varietal selection trials;
  (e) fulfilling reporting requirements, including preparing semiannual progress and financial reports, and preparing the final comprehensive report; and
(ii) help local teams in monitoring the adoption of improved varieties and assessing impacts.

6. With at least a master's degree in a relevant field, the plant breeders should be experienced in seed multiplication, dissemination, participatory varietal evaluation, survey, and impact assessment.

7. **Research assistants** (2 persons each for 24 person-months, total 48 person-months). Under the supervision of the senior scientist and the rice breeder, the two research assistants will

(i) develop mapping populations using identified donors for increased nematode tolerance and increased nutrient uptake in water-limited conditions; and
(ii) identify quantitative trait loci (QTLs) for nematode tolerance and QTLs for root traits for higher nutrient uptake under water-limited conditions to further increase yield under aerobic water-saving conditions.

8. The research assistants should be PhD students enrolled in a relevant program, with research experience in identifying QTLs for nematode tolerance and QTLs for root traits that lead to greater nutrient uptake under water-limited conditions.

B. National Consultants

9. **Senior research technicians** (3 persons each for 24 person-months, total 72 person-months). Supervised by the rice breeder, the senior research technicians will assist in

(i) planting the breeding lines in the IRRI field in appropriate water-saving conditions,
(ii) recording detailed observations in each experiment, and
(iii) recording observations and providing assistance in carrying out laboratory experiments.

10. The senior research technicians should be qualified at IRRI experimental analyst level and experienced in plant breeding and water monitoring.

11. **Junior research technicians** (2 persons each for 24 person-months, total 48 person-months). Supervised by the rice breeder, the junior research technicians will assist in

(i) land preparation, irrigation, and harvesting of the experiments;
(ii) threshing, blowing, drying, and weighing of the yield from each experimental unit;
(iii) seed preparation for experiments at IRRI; and
(iv) seed cleaning and seed preparation for exporting seed to national partners.

12. The junior research technicians should be qualified at IRRI field operator level and experienced in plant breeding and water monitoring.