Adapting Rice Technologies to Climate Change

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Abstract: Rice is prime crop that contributes to food security and provides employment to a large number of populations in Nepal. More than 51% of the area of rice land in Nepal is rain-fed. Over the last few years, however, the country has been experiencing erratic rainfall, with less water available for rice cultivation, as well as temperature rise. There are both submergence (flooding) problems and drought in the main rice growing areas. Hence, there is a need to generate suitable rice technologies under such adverse conditions.

The International Rice Research Institute (IRRI) has initiated research in collaboration with the Nepal Agricultural Research Council (NARC) and the Institute of Agriculture and Animal Sciences (IAAS) to develop suitable rice technologies for submergence and drought prone areas of Nepal. Various rice germplasm was brought from IRRI, Philippines, and research was conducted at NARC and IAAS as well as in farmers' fields following a program of Participatory Varietal Selection (PVS). Water-saving rice technologies as well as other technologies, including indigenous practices, were identified for utilizing less water for rice cultivation. Several varieties of rice under drought prone and under submergence conditions were identified, and have been recommended for cultivation by Nepalese farmers.

Key words: Rice technologies, drought, submergence, alternate wetting and drying (AWD), Nepal

Background

Major changes in temperature, solar radiation and precipitation affect crop productivity. The magnitude and geographical distribution of such climate induced changes might affect the world's ability to increase food production enough to feed the growing population. Rice is a staple food for 3.5 billion poor people of world; it is grown on more than 155 million hectares (m.ha.) and accounts for one-fifth of the global calorie supply (Pandey 2011). Water makes up 70% of the planet. But in spite of this vast availability, the fresh water reserve is finite. Over the years, improper use has led many to waste this precious natural resource, with direct effects on the world's food supply balance. This is particularly so regarding rice – the staple food of about 3 billion people (Bauman and Aureus 2009).

Like all other plants, rice needs water to survive. However, unlike most plants, it needs twice as much water to produce good yields. For 1 kg of paddy rice, an average of 2,500 liters of water needs to be supplied by rain and/or irrigation (Bauman and Aureus 2009). Fresh water for agriculture around the world is becoming increasingly scare, thereby threatening rice productivity and, consequently, the world's overall food supply. The causes of increasing water scarcity are diverse and location specific. They include: falling groundwater tables, chemical pollution, malfunctioning of irrigation systems, and increased competition from other sectors such as urban and industrial land use.

Drought stress severely limits rice productivity in the rainfed ecosystem, in which farmers often experience total crop failure at one critical plant growth stage or another. In rainfed areas erratic distribution and water shortage particularly affect the rice flowering and grain-filling stages, which can seriously curtail productivity. Asia alone has around 23 m.ha. (20% of the total rice area) prone to drought, where climate change will cause severe water scarcity (Reyes 2009).

Due to flooding, farmers in Bangladesh and India suffer annual crop losses of up to four million tons of rice – enough to feed 30 million people (Barclay 2009). Flooding can be truly disastrous to farm families and workers, and to poor consumers who rely on rice for the bulk of their food. In Nepal, the flooding problem occurs in the southern part of the country during the monsoon.

Rice is the prime crop of Nepal, covering 1.496 million ha with productivity of 2.981 ton/ha and total production of 4.46 million tons annually; it contributes 23% to the country's agricultural gross domestic product (GDP) (MOAC 2009). It accounts for 52% of the total food grain production and about 46% of the agricultural area, and it employs 65.6% of the population. It also meets more than 50% of the total calories requirement of the Nepalese people (MOAC 2009).

Issues

Unfavorable rice environment

Unfavorable rice environments are defined as those areas where rice production is frequently constrained by abiotic stresses such as drought, submergence, and adverse soil conditions. Most of these conditions are found where rice production is dependent on rain only, as in rainfed rice; but these also occur in irrigated or partially irrigated systems.

The most important rice-based rainfed system in Asia with respect to area number of dependent households is the rainfed lowland ecosystem, which covers about 46 m.ha. or almost 30% of the total rice area worldwide (Haefele and Hijmans 2007). They also indicate that other rainfed systems comprise upland rice (about 8.9 m.ha. in Asia) and in these areas multiple abiotic constraints often prevail. The most important abiotic stresses affecting rice production are drought (approximately 23 m.ha. regularly affected) and submergence (approximately 20 m.ha. regularly affected) (*Ibid.*).

Climate and soil related abiotic stresses are already widespread in rice-based cropping systems in Asia. Climate change, which is predicted to cause higher temperature, more extreme rainfall events, and a considerable sea level rise, is likely contribute with the result of these stresses becoming more common and more severe. To address existing and future abiotic stresses in unfavorable environments, a combination of improved germplasm and adjusted Crop and Natural Resource Management (CNRM) options are necessary.

Effect of drought

Worldwide, water for agriculture is becoming increasingly scare. By 2011, 15 to 20 m.ha. of irrigated rice may suffer from some degree of water scarcity (Bouman and Aureus 2009). It is estimated that about 38% of the world area, which is home of 70% of the total population and provides 70% of the global food production, suffers from drought. The effects of this problem are massive and devastating for rice farmers, who need to plant the crop that feeds half of the world's population.

Around 14 m.ha. of rice in India is subjected to drought stress and apart from around seven m.ha. of upland areas and other areas that are basically rainfed and are subject to drought either in the beginning or end of the season depending upon the late arrival or early retreat of the monsoon (Adhya 2010). With the erratic nature of the monsoon that is anticipated due to changed climate, the requirement of drought tolerant rice cultivars has been highly felt. In Nepal, rainfed rice covers 51% of the rice areas, including rainfed lowland and upland rice, while 49% of rice is either fully or partially irrigated (MOAC 2000/01). Drought, excess submergence water, and poor soil conditions are common constraints to rice production in rainfed lowland areas of Nepal (Choudhary, Mahato et al 2004).

Without assured irrigation, farmers are completely dependent on rainfall to water their crops. The possibility of drought has made rice farming a risky endeavor. Because of the risk, farmers do not invest enough inputs to increase rice production.

Effect of submergence

With climate change, monsoon rains are expected to become more erratic with changes in frequency, although the total season rainfall might remain similar or marginally greater. Erratic monsoon and extreme weather events such as unexpected heavy rains have inundated wide areas across many regions of Asia in recent times causing flooding and submergence. In India, around six m.ha. of rice area is affected by flash flooding in shallow and medium deep water environments (Adhya 2010). In these situations, currently farmers are growing varieties moderately tolerant to submergence, but these tend to have low yields.

In Nepal, the rice crop has been suffering from low and erratic rainfall. Irrigation facilities are limited and farmers have to grow rice with monsoon rains. At the same time, there are some submergence areas in the southern part of the country, where short period of water stagnant (10-15 days) has created problems during the heavy monsoon rains and farmers have been sacrificing the rice crop under such circumstances.

Research and Development Initiatives

To address the problem of drought due to water scarcity and temporary submergence (1-2 weeks) due to flooding, different research and development projects on rice crop were initiated at regional basis by the International Rice Research Institute (IRRI), Philippines.

Stress-Tolerant Rice for Poor Farmers in Africa and South Asia (STRASA)

Seventeen countries are participating in the STRASA project (Stress-Tolerant Rice for Poor Farmers in Africa and South Asia). In South Asia these are Bangladesh, India and Nepal. In West Africa they are Nigeria, Benin, Senegal, Burkino Faso, Ghana, Guinea, The Gambia, and Mali; and in Eastern and Southern Africa they are Mozambique, Tanzania, Uganda, Ethiopia, Madagascar, and Rwanda. These countries have major rainfed rice production areas that are affected by abiotic stresses.

The charitable purposes of the STRASA project are to reduce poverty and hunger and increase food and income security of resource poor farm families and rice consumers through the development and dissemination of rice varieties tolerant to abiotic stresses. The first phase of the project was from 2008 to 2010 (3 years) and the second phase has been extended from 2011 to 2013. The project has been supported by the Bill and Melinda Gates Foundation (BMGF) and launched by IRRI, Philippines.

Developing and disseminating water-saving rice technologies in South Asia

Bangladesh, India, Nepal, and Pakistan are the collaborating countries in this project, initiated in 2005 and completed in 2008. The overall goals were to enhance the food and income security of the rural and urban populations in South Asia through increased productivity and sustainability of rice production systems in water shortage and drought-prone regions, and to limit the diversion of water to rice production, saving it for other productive purposes. The project was launched by IRRI, with financial assistance provided by the Asian Development Bank (ADB).

Enhancing farmers' income and livelihoods through integrated crop and resource management in the rice-wheat system in South Asia

The Rice-Wheat Consortium (RWC) countries (Bangladesh, India, Nepal and Pakistan) were the main collaborators in this project, which was launched by IRRI with ADB financing, from 2005 to 2008. The overall goal of the project was to reduce rural poverty, improve farmers' livelihoods, and promote resource conservation in rice-wheat cropping systems in South Asia.

Management of rice landscapes in marginal uplands for household food security and environmental sustainability

This project was carried out in India, Nepal and Bangladesh in South Asia, and in the Lao PDR and Vietnam of Southeast Asia. This project was launched by IRRI with financial support by the International Fund for Agricultural Development (IFAD), from 2005 to 2008. It had three purposes: (a) identify, validate, and deliver improved rice technologies that raise the productivity of paddies, thereby relieving cropping pressure on fragile, slopping uplands; (b) identify, validate and deliver improved rice technologies for sloping uplands, where farmers currently practice shifting/rotational cultivation; and (c) identify institutional and policy improvement options appropriate to local socio-economic conditions to facilitate rapid uptake of improved technologies.

Cereal Systems Initiative for South Asia (CSISA)

The CSISA project was carried out in four South Asian countries: Bangladesh, India, Nepal and Pakistan. It was begun in 2008 initially for three years up to 2011, but most likely it will be extended for another seven years.

The project was designed to (a) develop new rice and wheat varieties with at least 0.5 tons per hectare attainable yield increments under farm condition; (b) develop rice, wheat and maize with improved nutritive value of their residues; (c) increase farm level yield and yield stability of rice, wheat and maize by 15% on 6 m.ha. and by 30% on an additional 2 m.ha. of harvested cereal area; (c) generate US$ 1.9 billion annually from the value of the increased grain production, not counting additional value generated from increased benefits from straw and stalks, and on-farm diversification and improved storage; and (d) increase by 30% the nitrogen- and water-use efficiency for rice and wheat crops grown in improved cropping systems. The project was launched jointly by IRRI, CIMMYT (International Maize and Wheat Improvement Center), IPRI (International Policy Research Institute), and ILRI (International Livestock Research Institute).

Options of Rice Technologies Generated under Stress Conditions

A. Drought tolerant varieties developed

To help farmers, IRRI has bred several new lines that perform well under drought conditions and are high-yielding. These varieties were brought to Nepal under the collaboration of IRRI and NARC as well as Institute of Agriculture and Animal Sciences (IAAS), were evaluated under drought conditions in research as well as on farmers' fields, and were found most suitable and preferred by the farmers.

The varieties released in Nepal and their conditions and results are:

a. Sukha Dhan 1 (IR71374-46-1-1), Sukha Dhan 2 (IR71374-54-1-1) and Sukha Dhan 3 (IR71374-70-1-1) released for drought conditions from the Terai lowlands to the foothills of Nepal. Yield potential of these varieties is 3.5 t/ha. These varieties mature in 125 days (Sukha Dhan 3 and Sukha Dhan 2 have also been released in the India and Philippines, respectively, with different names).

b. Tarahara 1 (IR80411-B-49-1) has been released in Nepal for drought conditions. This variety was found drought tolerant under the research as well as farmers' field conditions; it is especially to drought at the flowering stage, which can result in 75% more yield than normal rice varieties. It matures in 135 to 140 days and is suitable for the direct seeding. Yield potential is 4.5 to 5.0 t/ha.

c. Hardinath 1 is recommended for spring rice but can also be grown in the normal rice growing season. It matures early and can be grown successfully under drought conditions. It matures at 100 days and has a yield potential of 4 to 5 t/ha.

d. Hardinath 2 (B6144F-MR-6-0-0) is recommended for drought conditions. It matures at 110 to 115 days under direct seeded rice (DSR) conditions, and 125 days for transplanted condition.

e. Radha 4 is also recommended for drought conditions. It has yield potential of 4 to 5 t/ha and matures at 130 to 135 days.

f. Ghaiya 1 is a good for upland direct seeded rice (DSR). It is drought tolerant, matures in 115 days, and has a yield potential of 3.5 t/ha.

g. Cold tolerant rice varieties such as Chhromron Dhan, Machha Puchhre 3, Chandan Nath1 and Chandan Nath 3 have been released in Nepal for the cold areas.

h. Soils of Nepal are not saline and alkaline because our soils do not have high sodium salt content as well as high pH. Therefore, we do not have salinity and alkalinity problems in Nepal. However, there are a lot of saline and alkali soils in India, Bangladesh and Pakistan. These countries have released salinity tolerant rice varieties in their saline areas.

B. Submergence tolerant varieties developed

At IRRI, 'SUB1' gene has been successfully introduced into Swarna and Sambha Mahsuri through marker assisted back cross breeding. These sub1 varieties were brought to Nepal under the collaborative project of IRRI and NARC for abiotic stress conditions and, after research studies, these varieties are identified as suitable for submergence conditions, which is more frequent during July and August in the lowland Terai region. These varieties can withstand from 14 to 17 days of submergence and can give four to five t/ha yield after regeneration, which is not found in our normal varieties.

Swarna Sub1 and Sambha Mahsuri Sub1 have been released for the submergence conditions of Nepal (as well as in Bangladesh and India). These varieties can mature at 145 to 150 days. Both varieties have good eating quality; Sambha Mahsuri is of fine quality and most liked by farmers for home consumption.

Variety management technologies developed

Alternate Wetting and Drying (AWD)

AWD is a water-saving technology that lowland rice farmers can apply to reduce water use in irrigated fields. In AWD, irrigation water is applied to flood the field after a certain number of days have passed following the disappearance of ponded water. Hence, the field is alternately flooded and not flooded. The number of days of non-flooded soil in AWD in between irrigation can vary from one to more than ten.

A practical way to implement AWD is to monitor the depth of ponded water in a field using a field water tube. After irrigation, the depth of ponded water will gradually decrease. When ponded water drops to 15 cm below the soil surface, irrigation should be applied to re-flood the field upto 5 cm. From a week before until a week after flowering, ponded water should always be kept at 5 cm depth. After flowering, and during grain filling and ripening, the water level can be allowed to drop again to 15 cm below the surface before re-irrigation.

A farmer can start AWD a few days after transplanting (or with a 10 cm tall crop in direct seeding). If there are too many weeds, AWD can be postponed for 2-3 weeks until the ponded water suppresses weed growth.

It was found that there is no need to continuously maintain water in the rice field. IRRI has devised a simple way to check when rice crop needs water. A 40 cm long pipe with holes is drilled and pushed into the soil to a depth of 15 cm below the surface in different parts of the fields, with the remaining parts of the pipes above the soil surface. The pipes are made of PVC or bamboo and are perforated with small holes to allow water to enter inside the pipe. When the level of water inside the pipe falls beyond 15 cm from the soil surface, farmers can irrigate their fields. During this period there is alternate wetting and drying (AWD) in the fields. Thus, AWD can save 40% water in the rice field.

Direct Seeded Rice (DSR) or Aerobic Rice Technology

In DSR or aerobic rice technology, rice seeds are directly broadcast or sown in lines without puddling the soil. Nowadays, DSR is becoming popular in the farmers' field of Terai lowlands because of unavailability and high cost of labor for puddling and transplanting of rice. The yield of rice in DSR can vary from 2.5 to 4.0 t/ha, depending on the control of weeds, fertilizer use, and other management practices. This technology also saves water in water shortage conditions.

Weed Management in Aerobic Rice

Weed control is most important in direct seeded or aerobic rice. Weed management in rainfed uplands indicated that pre-emergence herbicide spray (Butachlor 1 kg a.i./ha) plus one hand weeding after three weeks of sowing was found economical and profitable. Secondly, herbicide application reduced the labor cost by 40%.

Cropping System Technology

Among the aerobic rice-based cropping systems (rice-rice, rice-wheat and rice-mungbean), the rice-mungbean system was more profitable and improved soil fertility by reducing application of nitrogenous fertilizer.

Integrated Crop and Resource Conservation/ Management in Rice-Wheat System

Integrated Crop Management (ICM) strategy significantly improved grain yields of both rice and wheat. On an average, ICM produced 1.1 t/ha higher rice grain yield over the farmers' practice. Similarly, in wheat, ICM gave higher grain yield of 31% as compared to farmers' practice. Higher benefit was observed in ICM than farmers' practice.

In zero till wheat, wheat seedling can be advanced by 7-15 days earlier and reduces yield loss and thus increases wheat yield. Wheat yield produced by zero till was 3.1 t/ha compared to 2.1 t/ha in farmers' practice.

With power tiller, seeding of wheat can be done in relatively higher soil moisture and thus seeding can be advanced by 7-15 days. In the lowland Terai, grain yield with power tiller was 3.2 t/ha compared to 2.2 t/ha in farmers' practice.

Addition of organic materials such as manures/ compost, mixture of manures and compost, green manures, crop residues in rice and non-rice crops has helped to retain soil moisture as well as balanced plant nutrients in the soil.

Leaf Color Chart (LCC)

The Leaf Color Chart (LCC) has been developed as a tool for farmers to assess the nitrogen (N) needs of their crops. The use of LCC has increased the efficiency of urea fertilizer use enabling farmers to harvest more rice with less expense for purchased fertilizers. Therefore, to minimize losses and increase the nitrogen efficiency, crop need based N management can be done with the use of LCC.

Transfer of Technologies

The Nepal Agricultural Research Council (NARC) and the Ministry of Agriculture and Cooperatives/Department of Agriculture (MOAC/DOA), as well as International Non-government Organizations (INGOs) and Non-government Organizations (NGOs) working in agricultural research and development have been disseminating and extending rice and non-rice crops technologies to the extension workers and farmers through electronic and printed media. In addition, organizing farmers' field days, training and exposure visits to the extension workers and farmers as well as interactions between technicians and farmers are some of the other techniques for the transfer of technologies followed in Nepal.

Conclusion and Recommendations

Drought and submergence tolerant rice varieties as well as management of rice and non-rice crop technologies are available in Nepal. These technologies should be demonstrated in the large areas in farmers' fields so that the impact of technologies can be seen when productivity of rice and non-rice crops increases. Then food security of the country will be enhanced in the context of climate change.

Future strategies should include:

a. Develop multiple stress tolerant rice varieties along with drought and submergence tolerance with anaerobic germination.
b. Develop varieties that can withstand prolonged submergence (beyond 15 days), with tolerance of clear and turbid floodwater.
c. In view of the higher ambient temperatures likely to prevail, develop varieties that can retain fertility at higher temperature, fill grain with higher day temperatures at grain filling stage, and maintain grain quality in these conditions.
d. Develop appropriate crop and natural resource management (CNRM) technology to provide maximum nutritional support to the growing crop.
e. Develop and adapt farmer-friendly strategies for growing crops in a changed climatic condition.

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