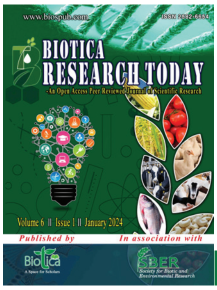

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Upland Rice: A Water-Efficient Rice Production System in India

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Abstract

The rainfed upland ecosystem, although often overlooked, plays a crucial role in sustaining India's impoverished population with its limited resources. This ecosystem spans across most states in the country, covering approximately 7 million hectares, with Eastern India having the highest coverage (>90%). In the typical upland ecosystem, rice is cultivated using direct seeding, employing minimal inputs such as fertilizers, insecticides, fungicides and herbicides. Upland rice farming is widely recognized for its crucial role in sustaining subsistence agriculture, catering to the nutritional needs of rainfed farming communities during the period of scarcity, particularly towards the end of September. Among all rice ecosystems, the upland environment stands out as the most diverse. Upland rice is cultivated through various methods, including permanent cultivation, block rotations, slash-and-burn (*Jhum* cultivation) and is established through broadcasting, seeding behind plough, or drilling seeds in small holes. It is grown both as a single crop and in combination with other cereals, oilseeds, or pulses. In specific regions like eastern Uttar Pradesh and West Bengal, short-duration upland rice is grown under transplanted conditions. The harvest from upland rice not only serves as a crucial food source for impoverished farmers but also fulfills the feed requirements for cattle during times of scarcity. The majority of upland rice cultivation is concentrated in the Eastern Plateau and Hills Region, emphasizing subsistence farming. Addressing such challenges is crucial for maximizing the potential of upland rice cultivation and its role in sustaining rainfed agriculture in India.

Keywords: Ecosystem, Rainfed, Short-duration, Subsistence

Introduction

Rainfed farming has great importance in Indian agriculture. This system provides food security to the poor people of India despite various crises and limited resources. An important part of rainfed agriculture is upland rice cultivation, which is grown in dry soils as opposed to flooded rice fields. In this particular type of agriculture, rice is grown under direct sowing using minimal fertilizers, pesticides, fungicides and herbicides. This particular system is prevalent in most of the states of India, especially in eastern India, where it covers an area of about 7 million hectares. Rainfed agriculture is proving to be an important resource for Indian farmers, which is providing them with opportunities despite problems and crises. Today, approximately 100 million people around the world rely on rainfed rice as it forms an integral part of daily staple diet. The upland rice region covers two-thirds of the world, including countries such as Bangladesh, Cambodia, China, North-east India, Indonesia, Myanmar, Nepal, Thailand and Vietnam. The specialty of upland rice is that it grows during the rainy season. When there is a shortage of food items for poor households during the lean period (end of September), rice cultivation on the uplands becomes an important source for rainfed farming households. This farming method brings positive changes

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because it uses less water and resources. Along with this, it helps in providing more income and security to the farmers. The upland paddy crop feeds families of marginal farmers and also fulfils the fodder requirement of the cattle. Rainfed agriculture is a socially important approach that helps promote food security and affordability.

Status of Rice Production in Upland Areas in India

Rice, which is one of the main crops of the country, is produced in various regions, but the level of production remains discreet here. Approximately 13% of the rice cultivation area in India is dedicated to upland rice, yet it contributes a mere 4% of the total rice production. The main reasons are several stresses that reduce rice yields in rainfed upland areas (Yadav *et al.*, 2013). These areas tend to belong to resource-poor farmers who face these types of conditions. A substantial area is covered, especially in the southern and western parts, such as Jharkhand, Orissa, Chhattisgarh, eastern Uttar Pradesh, parts of Assam, West Bengal and North-eastern states. The upland rice regions are usually focused in the eastern part, particularly in the Eastern Plateau and Hills Region, where the majority of the land under upland ecosystem is located. In this area, upland rice is predominantly grown for subsistence farming (Singh *et al*., 2014). One of the characteristics of upland rice is that it provides livelihood to farming families during lean seasons, as rice can be harvested early on the uplands (Priyanka *et al.*, 2012).

Rainfed Upland Rice Cultivation

The upland rice exhibits the highest diversity among all rice ecosystems. Upland rice is cultivated throughout the year using permanent systems, following block rotation, or employing the slash-and-burn method (*Jhum* cultivation). It is established through methods such as broadcasting, sowing seeds behind the plough, or placing seeds in small holes. This type of rice is grown both in mono-cropping and mixed cropping with other cereals, oilseeds, or pulses. In regions like eastern Uttar Pradesh and West Bengal, short-duration paddy is cultivated using transplanting method.

Upland rice is prepared like wheat or corn and seeded when dried. Upland rice-associated ecosystems are often relatively diverse - such as flat, steep-sided fields (Figure 1).

Figure 1: Upland rice in hilly terrain of North-east India

Area and Distribution

Rice, a staple crop essential to numerous cultures worldwide, finds its roots deeply embedded in the agricultural landscapes of India, China, Thailand, USA, Egypt and Indonesia. Across these nations, India boasts the largest cultivation area, closely trailed by China and Indonesia. When it comes to production volume, India secures the second position, standing just after China. Interestingly, in terms of yield hectare^{-1}, Egypt leads the pack, closely followed by the USA. Within India, rice cultivation paints a comprehensive map, spanning across almost every state, including Andhra Pradesh, Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, West Bengal Punjab and North-eastern states. Notably, among these states, West Bengal and Uttar Pradesh emerge as the leaders in rice production. However, Punjab shines bright in terms of the highest average yield hectare^{-1}, showcasing the diverse and dynamic nature of rice cultivation patterns and successes across these regions.

Significance of Economics

Rice stands as an indispensable staple worldwide, alongside wheat, sorghum and maize, feeding countless communities globally. In the heart of south-east Asia, it holds the esteemed title of being the primary sustenance for a majority of the population. India, in particular, venerates rice as its most crucially cultivated food crop, encompassing the agricultural landscape and serving as the fundamental diet for over 70% of its people. Beyond its significance as a dietary cornerstone, rice distinguishes itself as a high-energy crop, boasting substantial caloric contributions. However, in terms of protein content, it falls slightly behind its counterpart, wheat, with milled rice typically containing around 6-7% protein. Despite this disparity, rice impressively matches wheat in its concentration of 'B' group vitamins, further highlighting its nutritional value.

The multifaceted uses of rice extend beyond human consumption. Rice bran finds purpose as feed for livestock, enhancing the quality of cattle and poultry sustenance. Additionally, the versatility of rice hulls manifests in various industries, contributing to the production of insulation materials, cement and cardboard along with serving as a vital component in poultry care, employed as litter. Even rice straw doesn't go to waste, finding dual utility as both cattle feed and winter litter, emphasizing the holistic value of this revered crop. Rice's economic importance transcends mere sustenance, interweaving itself into the fabric of agriculture, nutrition and various industries, underscoring its integral role in global economies and daily lives.

Soil and Climate: Harmony Below and Above

Upland rice cultivation demands a precise blend of soil quality and climate conditions for optimal growth. Ideal soils for this purpose exhibit excellent water retention capabilities, boasting a substantial presence of clay and organic matter. Sandy loam to clay loam soils stand out as the prime choice, ensuring a conducive environment for upland rice cultivation. A key prerequisite is the soil's high water-holding capacity, as water-logged soils prove unsuitable for this crop. Moreover, richness in organic matter and essential nutrients is pivotal for robust growth. Maintaining a pH range of 5.5-6.5 fosters an ideal soil environment.

Regarding climate, upland rice thrives in regions characterized by high humidity and a consistent water supply. Its tropical inclination dictates a preference for hot and humid conditions throughout its growth cycle. An average temperature range of 21-37 °C is congenial for this crop, with specific temperature needs varying during different growth stages. From tillering to blooming and ripening, distinct temperature requirements ranging from higher temperatures for tillering to a narrower range for blooming and ripening stages are critical for successful yield. Furthermore, upland rice typically responds to short-day conditions, although some varieties have adapted to be less sensitive to photoperiodic influences. Understanding and harmonizing these soil and climate prerequisites are crucial for maximizing upland rice yields.

Suitable Varieties

Different types of rice varieties include APHR-1, APHR-2, Pusa Basmati, TN-1, IR-8, IR-22, Ambemohar, Karjat-184, Ratnagiri-24, Indrayani, Palghar-1, Sahayadri, Punjab Basmati, ADT-37, ADT-38, ADT-39 and more (Table 1).

Table 1: Suitability of upland rice varieties based on different conditions

Conditions	Variety suitable to the conditions
Congenial	Vandana, CR Dhan 40, Anjali, CR Dhan 103, Purna, *etc*.
Uncongenial	Sadabahar, Gangavati Ageti, Sahbhagidhan

Field Preparation

1. Following the harvest of *rabi* crops around April-May, utilize a soil turning plough to plough the field.

2. Conduct 2-3 harrowing processes subsequently to enhance soil porosity. This practice aids in weed elimination and enhances the soil's ability to retain water.

3. Post this; create bunds around the paddy field immediately once the initial monsoon rainfall is received.

Seeds and Sowing

1. Seed quantity:

i. Broadcasting: 100 kg ha^{-1}

ii. Drilling: 60 kg ha^{-1}

2. Plant spacing: 20 × 20 cm or 20 × 15 cm

3. Optimal sowing period: June to July

4. Depth of sowing: 3 to 4 cm

5. Sowing techniques: Broadcasting, Drilling, *etc*.

Seed Treatment

1. Application of fungicides such as Bavistin, Thiram, or Captan at a rate of 3 g kg^{-1} of seeds before sowing aids in managing blast, brown leaf spot and sheath blight diseases.

2. Soaking seeds in a 3% Brine solution (300 g $CaSO_4$ + 10 litres of water) for 12-24 hours is effective in controlling rice blast disease.

3. Healthy seeds can be obtained from mechanically separated seeds using 20% common salt solution which can manage sheath rot in varieties of 90-105 days duration.

4. Treating seeds with Emisan at a rate of 5 g/ 10 kg seeds in 10 litres of water helps combat bacterial blight and sheath blight diseases.

5. Treating seeds with biofertilizers like *Azotobacter* or *Azospirillum* at 25 g kg^{-1} of seeds enhances non-symbiotic atmospheric nitrogen fixation.

Nutrient Management

1. Thorough incorporation of 10-15 tonnes hectare^{-1} of Farm Yard Manure (FYM) or compost 2-13 weeks before sowing.

2. Fertilization with either 60:30:30 or 80:40:40 kg of NPK (Nitrogen, Phosphorus, Potassium) ha^{-1}. Apply 25% of nitrogen and the full doses of phosphorus and potassium during land preparation.

3. Provide the remaining 50% of nitrogen during the tillering stage and rest 25% at panicle initiation stage.

4. Iron deficiency can be managed by employing a foliar spray of 0.5% $FeSO_4$.

5. Zinc Sulphate (10 kg acre^{-1}) or zinc-EDTA (6 kg acre^{-1}) at final land preparation in cases of Zn deficiency.

6. For soil lacking in boron, apply Borax at a rate of 2 kg acre^{-1} during the final land preparation.

7. Applying nutrients judiciously, either through the Nutrient Expert or LCC, can serve as a practical choice for managing nutrients in directly seeded upland rice.

8. The economically viable method for sustainable upland rice production in Meghalaya, under organic management, involves the balanced use of farmyard manure (FYM), vermicompost (VC) and poultry manure (PM) at equal proportions (25% each). This approach, combined with the application of Phosphorus Solubilising Bacteria, is recommended (Tripathy *et al*., 2020).

Water Resources Management

1. Sufficient rainfall obviates the necessity for irrigation; instead, irrigation becomes crucial during critical growth stages in the event of delayed or inadequate rainfall.

2. CSI (Critical Stage of Irrigation): tillering, panicle initiation, grain filling and milking stages.

3. For its entire life cycle, upland paddy crop typically demands 5-6 irrigation sessions.

Managing Weeds

1. Problematic weeds: *Cyperus rotundus* and *Cynodon dactylon*.

2. CPCWC (Critical Period of Crop Weed Competition): 30 to 40-day period after sowing. Failure to control weeds during this phase can result in yield reductions of up to 50% or more.

3. Effective weed management involves a combination of mechanical and chemical methods. Using a blade or wheel hoe for two sessions at 15-20 and 30-40 days after sowing, followed by manual weeding, proves effective.

4. The pre-emergence herbicide pendimethalin (Stomp) applied at rates of 1-1.5 kg ha^{-1} demonstrates efficacy in weed control.

5. Herbicide sprays like Butachlor, Propanil, or Benthiocarb at 1 kg a.i. ha^{-1} can aid in managing crop-weed competition.

6. Application of pre-emergence herbicide Pretilachor 50 EC (Rifit) @ 1.5 litre ha^{-1} 2 days after sowing followed by hand weeding at 30 days after germination.

7. To control weed growth in directly seeded upland rice chemically, it is advised to apply either 120 ml $acre^{-1}$ of Bispyribac sodium 10% SC 8-10 days after weed emergence (or when weeds reach the 2-3 leaf stage) with an 8-tank sprayer having a 16-litre capacity or 260 ml $acre^{-1}$ of Fenoxaprop-p-ethyl 9 EC 20 days after weed emergence in moist soil.

8. Bensulfuron methyl 0.6% + Pretilachlor 6% GR at a rate of 4 kg $acre^{-1}$ + 4 kg of sand, 5-10 days after transplanting (DAT).

Plant Protection

Major Pests

Several pests, such as the Rice Yellow Stem Borer, Gall Midge, Rice Hispa, Leaf Roller, Army Worm, Gundhi Bug, Green Leaf Hopper and Brown Plant Hopper, can seriously impact the health and productivity of rice crops. Managing these pests is crucial to safeguard the rice fields and ensure a fruitful harvest.

Management

1. Insect pest tolerant varieties: Anjali, Vandana, Abhishek.

2. For Gundhi bug: Need based application of Chlorpyriphos 20 EC (Hilban) @ 1.25 litre ha^{-1}.

3. For stem borer: Release of *Trichogramma japonicum* @ 1,00,000 ha^{-1} (5 trichocards ha^{-1}) at 30 days after sowing, use of pheromone trap @ 20 ha^{-1} for mass trapping, need based application of Chlorantraniliprole 18.5% SC (Coragen) @ 150 ml ha^{-1}.

4. For termite: Seed treatment with Chlorpyriphos 20 EC (Hilban) @ 7 ml kg^{-1}.

5. If thrips infestation is observed in the rice nursery, apply NSKE (Azadirachtin) (800 ml $acre^{-1}$), or Lambda-Cyhalothrin 5% EC (100 ml $acre^{-1}$), or Thiamethoxam 25% WG (40 g $acre^{-1}$).

6. Place three pheromone traps $acre^{-1}$ in the rice nursery to monitor the presence of stem borers and leaf folders. Once the count of male moths $trap^{-1}$ reaches 4 or 5, apply Azadirachtin 0.15% EC (800 ml $acre^{-1}$) or Chlorantraniliprole 0.4% GR (4 kg $acre^{-1}$), mixed with sand in a 1:1 ratio. Alternatively, Chlorantraniliprole 18.5% SC (60 ml $acre^{-1}$ in 200 litres of water), or Cartap hydrochloride 4G (10 kg $acre^{-1}$) can be recommended.

7. To manage case worm infestations, spray Indoxacarb 15.8% EC (80 ml $acre^{-1}$) or Flubendiamide 39.35% SC (20 ml $acre^{-1}$).

Major Diseases

Rice farming encounters a range of difficulties, including various diseases and nutrient deficiencies that pose significant threats to both crop health and yield. Some of the most problematic adversaries include rice blast, brown spot, stem rot, false smut and sheath blight, all capable of causing substantial harm to rice crops. Bacterial leaf blight, also known as 'Kresek,' is particularly concerning as it spreads rapidly during the early stages of crop growth. Additionally, bacterial leaf streak and the Tungro virus, transmitted by a virus, further increase the susceptibility of rice plants. Moreover, Khaira, linked to zinc deficiency, adds to the challenges, underscoring the complex nature of issues faced in rice cultivation.

Management

1. For blast: seed treatment with Bavistin @ 2 g kg^{-1} and need based application of Carbendazim 50 WP (Bavistin) @ 2 ml l^{-1} at 8-10 % leaf infection.

2. For brown spot: need based application of Mancozeb 75 WP (Dithan M 45) @ 1.2 kg ha^{-1} at 8-10 % leaf infection.

3. Before planting, it is recommended to treat the seeds with *Trichoderma* dust formulation at a rate of 10 g kg^{-1} of seeds (soak the paddy seeds in water for 8 hours, drain the water, then combine the seeds with *Trichoderma* dust formulation and finally store the mixture as a heap covered with a moist sack or polythene sheet for 12-24 hours before sowing in the nursery). Alternatively, seeds can be treated with Captan 50% (Capgold/Captara) or Thiram 75% (Thiram 75/Thirox) at a rate of 3 g kg^{-1} of seed, or any other alternative recommended by State Government agencies.

4. If seedling blight disease becomes evident, apply Propiconazole at a rate of 1 ml $litre^{-1}$ of water.

5. In the presence of leaf blast in the rice nursery, use Tebuconazole 50% + Trifloxystrobin 25% WG at 0.4 g or apply Isoprothiolane 40 EC at 1.5 ml $litre^{-1}$ of water for spraying. Repeat the spraying at intervals of 7-10 days.

6. To address Bakanae disease in the rice nursery, spray Carbendazim 50WP at 1 g or Carbendazim 64% + Mancozeb 8% 75WP at 1.5 g $litre^{-1}$ of water and repeat the spraying at 7-10 day intervals.

7. In case of brown spot incidence, apply Propiconazole 25EC at 1 ml or Mancozeb 75WP, or Carbendazim 64% + Mancozeb 8% 75WP at 1.5 g $litre^{-1}$ of water.

8. If rice tungro disease is present, control the green leaf hopper by applying Imidacloprid 17.8SL at a rate of 0.25 ml or Thiamethoxam 25WG at 0.2 g $litre^{-1}$ of water through spraying.

Harvesting and Yield

Harvesting rice is a meticulous process that hinges on timing for top quality and minimal loss. It involves closely observing the crop's changes, from leaves turning yellow to panicles shifting from green to golden, indicating maturity. When the grains attain maturity, they become firm and make a distinct metallic sound when tested between teeth. It is critical to harvest when around 80% of panicles display roughly 80% ripened spikelets. Optimal conditions mean aiming for the upper part of spikelets to look straw-coloured and maintaining a moisture content of about 20%. Using serrated sickles for precise hand-cutting near the ground is customary. Post-harvest, dried plants are bundled and left to dry further before employing various threshing methods like beating, use of machinery, or bullock trampling. Thorough cleaning and sun-drying of the threshed material ensure it is ready for subsequent processing, ensuring high-quality grains. The cultivation of upland rice poses significant challenges for farmers, particularly those in regions with limited resources. With an average yield of approximately 1 ton ha^{-1}, growing this type of rice proves to be an arduous task. However, the variability in yields is influenced by several critical factors, such as the number of seeds sown per hole. Studies reveal that planting three seeds increases the yield to 1.50 tons ha^{-1}, while two seeds result in 1.45 tons and using a single seed yields 1.43 tons ha^{-1}. Yet, the unpredictability of upland rice production extends beyond seed quantity, relying on factors like rainfall patterns and agricultural practices including fertilization and weed control. Furthermore, the inherent genetic potential of the rice variety and the application of fertilizers also impact production levels. For many of the world's most disadvantaged farmers, cultivating upland rice presents immense challenges due to unfavourable conditions marked by poor soil fertility, inadequate water supply and various constraints affecting yield, categorizing the region as a "low productivity" area.

Forecasting Tomorrow: A Glimpse into the Future

Over recent decades, technological advancements in rice cultivation primarily targeted irrigated rice, though some attention was given to upland rice. Researchers developed varieties tailored for poor soils, with enhanced pest resistance and drought tolerance. These efforts notably boosted conventional rice yields by over 100% in certain evaluations. Collaborations between scientists at the National Agricultural Research Systems led to hybrid varieties by crossing improved strains with local ones.

Significant growth has been observed in upland rice production, reaching nearly 10 million tons last year. States like Uttar Pradesh, Chhattisgarh, Jharkhand, Bihar and Odisha have shown notable increases in upland rice cultivation. These figures hint at the potential for further expansion and progress in rice farming. Recent research and technological strides have motivated numerous farmers to adopt improved practices for local rice production, positively impacting their economic prospects. Ongoing agricultural research and scientific advancements hold the promise of elevating upland rice production by 20-25%. This presents both a challenge and an opportunity for Indian agriculture in the foreseeable future. The advancement of upland rice cultivation not only stands to propel progress in the agricultural sector but also promises economic benefits for Indian society.

Conclusion

The majority of farmers are not benefiting from the latest knowledge and technologies due to ineffective extension efforts in this field. Extension services in numerous countries lack proper training and resources to effectively convey new information from researchers to farmers. This gap requires immediate attention. The delivery mechanism for technology needs a restructuring to accommodate evolving situations and effectively distribute sophisticated, knowledge-intensive technologies to farmers. It is vital to investigate the engagement of private sector extension agencies in commercial farming zones and other service-oriented organizations such as NGOs in areas focused on food crops. This is necessary to convey new knowledge and technologies to farmers. Improving the efficiency of different combinations of public, private, cooperative and NGO extension agencies is of utmost importance.

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