Africe Rice Center (WARDA)

Growing upland rice: a production handbook

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About Africa Rice Center (WARDA)

Africa Rice Center (WARDA) is an autonomous intergovernmental research association of African member states and also one of the 15 international agricultural research Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

WARDA's mission is to contribute to poverty alleviation and food security in sub-Saharan Africa (SSA) through research, development and partnership activities aimed at increasing the productivity and profitability of the rice sector in ways that ensure the sustainability of the farming environment.

WARDA hosts the African Rice Initiative (ARI), the Rice Research and Development Network for West and Central Africa (ROCARIZ), the International Network for Genetic Evaluation of Rice in Africa (INGER-Africa) and the Inland Valley Consortium (IVC). It also supports the Coordination Unit of the Eastern and Central African Rice Research Network (ECARRN), based in Tanzania.

WARDA has its headquarters in Cotonou, Benin and regional research stations near Saint-Louis, Senegal and at the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria. WARDA's main research center is in Côte d'Ivoire but most scientists and researchers are temporarily located in Cotonou.

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Contents

Preface	2
Introduction	3
The rice plant	4
Share of upland rice areas in Nigeria	5
Major upland production constraints	5
Choice of land	6
Land preparation	6
Recommended upland varieties	7
Choice of seed	7
Sources to contact for good quality seed	8
Seed viability testing and seed requirement	8
Seed treatment	9
Sowing time	10
Sowing methods	10
Spacing and seeding rate	10
Thinning seedlings	11
Fertilizers	11
Fertilizer application	12
Fertilizers recommendation	13
Fertilizer calculations	19
Legume–rice rotation systems	20
Weed control	22
Pests and disease control	24
Bird control	27
Harvesting	28
Threshing	29
Winnowing	30
Drying	30
Parboiling	31
Milling	32
Storage conditions	33
Control of storage pests	33
Further reading	34
Annex 1	35
Annex 2	36
Pesticide safety	37

Preface

Upland rice production accounts for 20% of the total rice produced in Nigeria. With the development of New Rice for Africa (NERICA) for upland production systems, a number of farmers have shown interest in growing upland rice. Unfortunately, these farmers do not have a ready source of information on upland rice production.

This handbook will provide a reference source for research and training of rice researchers, extension officers, MSc and PhD students, and farmers. It will also be a valuable document for research technicians and undergraduate agricultural students in colleges of agriculture and universities seeking practical information on upland rice production.

The handbook is based on experiences accumulated at the Africa Rice Center (WARDA) in Nigeria and elsewhere. The handbook covers every aspect of upland rice production from land preparation and seed to the plate.

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Introduction

Nigeria is the largest producer of rice in the West Africa sub-region. Today, rice is no longer a luxury food to millions of Nigerians but has become the cereal that constitutes a major source of calories for the rural and urban poor with demand growing at an annual rate of 5%. Urbanization, changes in employment patterns, income levels, and rapid population growth have significantly contributed to widening the gap between supply and demand for rice in Nigeria.

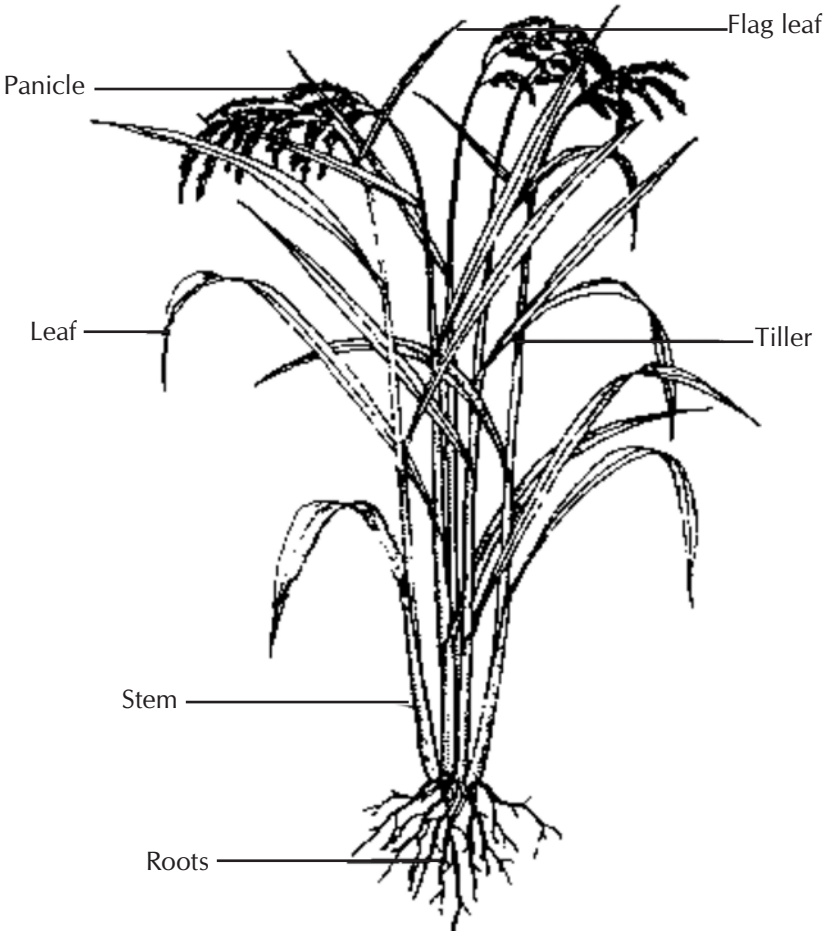
Nigeria has the potential and suitable agro-ecologies (upland, rainfed lowland, irrigated lowland, deep water and mangrove swamp) to attain self-sufficiency in rice production. The potential land area for rice production in Nigeria is estimated at 4.6 to 4.9 million hectares. But only about 1.7 million hectares of this land is presently being cropped to rice. The rainfed upland rice ecology represents 25% of the 1.7 million hectares.

With the recent breakthrough in the development of the New Rice for Africa (NERICA) for upland production systems and the high demand for rice, farmers' interest in growing upland rice has increased. Farmers and extension officers have repeatedly demanded information on how to grow/produce upland rice including the NERICA.

This handbook is an attempt to meet this demand with the hope that it will positively impact upland rice production and productivity in Nigeria.

The rice plant

A rice plant with four tillers



A tiller is a shoot different from the main stem and has roots and leaves. It may or may not have a panicle.

Table 1. Share of upland rice areas in Nigeria

Production systems	Major states covered	Estimated share of national rice area (%)	Average yield (tonne/ha)	Share of rice production (%)
Rainfed upland	Benue, Delta, Edo, Ekiti, Kaduna, Kebbi, Kogi, Kwara, Niger, Ogun, Ondo, Osun, Oyo and Sokoto States	30	1.7	20

Major upland production constraints

Biotic

- Weeds
- Insect pests
  - Stem borers
  - Termites
- Diseases
  - Blast
  - Brown spot
- Nematodes
- Vertebrate pests
  - Birds,
  - Rodents

Abiotic

- Drought
- Low soil fertility (N, P, K, Zn and Fe deficiencies)
- Soil acidity
- Soil erosion

Choice of land

- Select your site in an ecological zone with at least 14–20 mm of five-day rainfall during the growing cycle.
- Choose fertile land with good drainage and good water retention capacity (contains some clay and/or organic matter, i.e. loamy soil).
- If you have to grow rice for more than one consecutive year on the same piece of land, seek the advice of the Soil Survey and Testing Service of the Institute of Agricultural Research and Training (IAR&T) or any other reputable soil-testing unit.

Land preparation

1. Mechanization (forest area)

- For newly cleared areas, stump big trees before the rains, preferably from November to February, and remove all stumps, roots and trees before ploughing.
- Plow once and disc harrow twice with the first rains (from late February to early March in the south) to make a good tilth if land is flat.
- Plow and disc harrow once if the land is sloppy.
- Harrow two weeks after plowing to allow the weeds to die.
- Divide the field into plots of 50 m^2 or 100 m^2 and construct bunds, depending on the slope, to accumulate rain water and also to allow good drainage.

Land preparation using animal traction

- Level the field to reduce erosion.
- Apply basal fertilizer (P and K) before final harrowing (see more on fertilizer application for types and rates to use).

2. Manual cultivation

- Clear and pack thick bush between November and February.
- Use a hoe to remove thick bush but leave small debris and weeds to be incorporated as manure when hoeing.
- In the savannah, land preparation can start in February, depending on rain.

Farmers using hand hoes for land preparation

Good drainage

Recommended upland varieties

- Early maturing (< 90–100 days): FARO 1, 40, 45, 54, 55 (NERICA1), 56 (NERICA2), other upland NERICA.
- Medium maturing (100–120 days): FARO 48, 49, 53, etc.
- Late maturing (> 120 days): FARO 25.

Choice of seed

- Use good quality seeds with a high percentage of viability (> 80%) and without insect damage or contaminants (weed seeds, stones, other seed types).
- Avoid seed of mixed varieties.

Sources to contact for good quality seed

- State Agricultural Development Projects (ADP) that includes rice in its production programs.
- River Basin Development Authority.
- Branch office of the National Agricultural Seed Council.
- Seed Company.
- Other rice farmers.
- WARDA–Nigeria.

Avoid seeds of mixed varieties

Seed dormancy

- Dormancy is the failure of good quality mature seeds to germinate under favorable conditions. Dormancy of freshly harvested seed should be broken by using heat treatment at 50°C in an oven if available or by placing the seeds on a plastic sheet and covering with itself or another under direct sunlight for 1 or 2 days. Acid treatment may also be used.
- Acid treatment: soak seeds for 16 to 24 hours in 6 ml of concentrated nitric acid (69% HNO_3) per liter of water for every 1 kg of newly-harvested seeds. After soaking, drain acid solution off and sun-dry the seeds for 3 to 5 days to a moisture content of 14%. Store in dry conditions for sowing.
- Conduct germination test on seeds to establish rates to use based on seed viability.

Seed viability testing and seed requirement

- Use only filled grains of good quality for sowing: add water to seeds and discard all empty grains that float in water
- When the seed viability is not known, a simple seed viability test should be carried out to guide the actual seed rate to use

- Place moistened tissue paper (preferably filter paper, if available) in a dish with lid (use Petri-dish if available) and put in 100 randomly-selected filled seeds. Cover and keep the dish at room temperature for 4–5 days to germinate the seeds.
- Then count the number of sprouting seeds (only those with shoots > 1 cm). If 60 germinating seeds are counted, it means the viability rate is 60% (% of germination).
- If the seed rate is 50 kg/ha, for example, the actual quantity of seeds to be used for sowing can be calculated as follows:

$$\text{Seed required (kg/ha)} = \frac{\text{Seed rate} \times \text{Area to be planted}}{\text{\% germination}} \times \text{\% of filled grains}$$

$$= \frac{50 \text{ kg/ha} \times 1 \text{ ha}}{0.60} \times 1 \text{ (assuming 100\% filled grains)}$$

$$= 83 \text{ kg/ha}$$

- To estimate percentage filled grains, select at random 100 seeds from seed lot to be sown and count the number of filled grains. If 90, it means 90% filled grains.

Seed treatment

- Treat selected seeds with a mixture of insecticide and fungicide. For example, Apron Star™ 42 WS (thiamethoxam 20 g/l + difenoconazole 2 g/l + metalaxyl-m 20 g/l) at the rate of one sachet per 4 kg seeds, or any available seed dressing chemical before sowing.
- Other products can be used:
  - PROCOT 40 WS (carbosulfan + carbendazim + metalaxyl-m.
  - CALTHIO C 50 WS (thiram + chlorpyriphos-ethyl).
- In areas with termite and nematode problems, incorporate carbofuran (Furadan™) at the rate of 2.5 kg a.i. per hectare into

planting row. To ensure uniform application, Furadan should be mixed with sand at a ratio of 1:4.

- Soak seeds in water for 24 hours and incubate for 48 hours before sowing to ensure uniform seedling emergence and good establishment.

Sowing time

- Savannah agroecology: May to June.
- Forest agroecology: April to May.
- Allow rains to be well established before seeding.
- Sow seeds when the soil is moist; if possible immediately after a good rain.

Sowing methods

Direct seeding by:

- Dibbling: opening up a spot in the soil and sowing 5 to 8 seeds at a depth of 2–3 cm.
- Drilling: making a small groove, 2–3 cm deep in the soil, and sowing the seeds sparsely in the groove and covering with soil.
- Broadcasting: spreading the seeds on the soil surface without any specific pattern.

Spacing and seeding rate

- Dibbling at 30 × 30 cm or 20 × 20 cm: seed rate: 50–60 kg/ha.
- Drilling at 25–30 cm row spacing and 5 cm within row; seed rate: 75–80 kg/ha.
- Broadcasting: seed rate: 80–100 kg/ha.

Dibbling rice at a spacing of 20 × 20 cm

Note: Drilling and broadcasting are not recommended in early season drought-prone areas and if sufficient seeds and fertilizers are not available.

Thinning seedlings

Weeding and thinning of seedlings

- At 2–3 weeks after sowing, thin the seedlings to 2–4 per stand for dibble-seeded seedlings. This will give a final plant density of 22–44 plants/m^2 for 30 × 30 cm and 50–100 plants/m^2 for 20 × 20 cm spacing.
- But maintain only one seedling per stand for drill-seeded seedlings. To avoid overcrowding, ensure the distance between stands is 5 cm (final density = 80 plants/m^2).

Fertilizers

- Fertilizers supply nutrients essential for growth, nutrition and health of the rice plant.
- Fertilizers can be applied in organic or inorganic (mineral) forms or both.
- Organic fertilizer can be in the form of manure, compost or crop residues.
- Mineral fertilizers are manufactured. It is important to apply the right quantity and at the right time to obtain optimum yields and for environmental protection.

Types of fertilizer

- Straight (single) fertilizers: These supply only one primary nutrient (e.g. N, P or K) to the crop.
- Some examples:
  - Nitrogen: urea, ammonium sulphate, ammonium nitrate, calcium ammonium nitrate (CAN), and others.
  - Phosphorus: single super-phosphate (SSP), triple super-phosphate (TSP) etc.
  - Potassium: Muriate of potash (MOP; KCl).

- Compound fertilizers: These supply more than one nutrient (e.g. N, P and K) to the crop .
- Some examples:
  - NPK 15-15-15 (15% N; 15% P_2O_5; 15% K_2O);
  - NPK 20-10-10 (20% N; 10% P_2O_5; 10% K_2O);
  - NPK 30-10-0 (30% N; 10% P_2O_5; 0% K_2O);
  - Ammonium phosphate nitrate (APN).

Note: There is no specific compound fertilizer formulated for rice. In this handbook, the preparation of formulations from straight fertilizers for a specific recommendation for immediate application for rice production has been demonstrated.

Fertilizer application

- Fertilizer should be applied based on the residual nutrients in the soil from soil test results, the expected yield and the type of fertilizer materials available.
- The farmer should strive to obtain fertilizer recommendations based on analysis of soil samples. Table 2 can serve as a guide.
- In situations where it is not possible to conduct soil testing due to high costs and unavailability of analytical services, or when the farmer is running out of time because the crop is subnormal in growth, the general recommendations in this handbook should serve as a guide.

Fertilizer recommendation

Table 2. Nitrogen, phosphorus and potassium fertilizer recommendations based on soil testing[1]

Nutrient	Soil fertility class	Recommended rate (kg/ha)	Fertilizer source and rate (kg/ha)
Nitrogen[2]	Low (<1.0 g total-N/kg) Medium (1.0–2.0 g total-N/kg) High (> 2.0 g total-N/kg)	60–80 40–60 20–40	80 kg N≡ urea (174 kg or 3½ bags) 60 kg N≡ urea (130 kg or 2½ bags) 40 kg N≡ urea (87 kg or 1¾ bags) 20 kg N≡ urea (44 kg or ~ 1 bag)
Phosphorus	Low (< 8 mg/kg [Bray-1]) (< 15 mg/kg [Bray-2]) (< 7 mg/kg [Mehlich III]) Medium (8–20 mg/kg [Bray-1]) (15–25 mg/kg [Bray-2]) (7–15 mg/kg [Mehlich III]) High (>20 mg/kg [Bray-1]) (>25 mg/kg [Bray-2]) (>15 mg/kg [Mehlich III])	30–60 P_2O_5 15–30 P_2O_5 0–15 P_2O_5	60 kg P_2O_5 (333 kg or 6⅔ bags SSP) or 60 kg P_2O_5 (132 kg or 2⅔ bags TSP) 30 kg P_2O_5 (167 kg or 3⅓ bags SSP) or 30 kg P_2O_5 (66kg or 1⅓ bags TSP) 15 kg P_2O_5 (83 kg or 1⅔ bags SSP) or 15 kg P_2O_5 (33 kg or ⅔ bag TSP)
Potassium	Low (<0.2 Cmolc/kg) Medium (0.2–0.4 Cmolc/kg) High (> 0.4 Cmolc/kg)	30 K_2O 15–30 K_2O 0–15 K_2O	30 kg K_2O (50 kg or 1 bag MOP) 15 kg K_2O (25 kg or ½ bag MOP)

[1]*Modified from Fertilizer Use and Management Practices for Crops in Nigeria.*
[2]*Not commonly used to guide N needs of soils. Leaf color chart (LCC) serves as a better guide.*
[3]*centimol of charge = meq per 100g soil*

Method and time of application

- For acid soils or soils under continuous cultivation that are likely to be deficient in P and K, apply both phosphate and potash fertilizers at final harrowing before seeding.
- General recommendation: apply 60–80 kg N, 30 kg P_2O_5/ha and 30 kg K_2O/ha.

- For strongly acid soils (pH ≥ 4.8) or soils highly deficient in P, the rate of P should be increased to 60 kg P_2O_5/ha.
- Always apply K although most cases show no response to K (potash) application.

Basal application of P and K from straight fertilizers

- Best apply phosphate and potash fertilizers before seeding (at final harrowing) or before seedling emergence.
- To compound the recommended application: 30 kg P_2O_5/ha and 30 kg K_2O/ha straight fertilizers (phosphate and potash):

– Weigh 167 kg/ha (3⅓ bags) of SSP or 66 kg/ha (1⅓ bags) of TSP. Double the rates if applying 60 kg P_2O_5/ha (for highly P-deficient soils).
– Weigh 50 kg/ha (1 bag of MOP [potash]).
– Place both fertilizers on a concrete surface and mix thoroughly using a shovel or hoe.
– Bag and store in a dry place for application.
– Apply the mixture by broadcasting uniformly on the field before seeding (at final harrowing) or before seedling emergence.
– A list of common fertilizers is in Annex 1.

Basal application P and K from compound fertilizers

To supply the recommended application of 30 kg P_2O_5/ha and 30 kg K_2O/ha from NPK 15-15-15 fertilizer:

- Apply 200 kg/ha of NPK 15-15-15 by broadcasting uniformly on the field before seeding (at final harrowing) or before seedling emergence.
- Note that this will also supply N equivalent to 30 kg/ha as basal N.
- Therefore, to achieve the recommended N of 60–80 kg/ha, a further 30–50 kg N/ha (1⅓–2 bags urea) will then be applied as a topdressing in two splits as described under topdressing below.

Topdressing from straight fertilizers (e.g. urea)

General recommendations:

- Use 15 to 20 kg N for every tonne of target (expected) yield.
- Apply in 2–3 splits for ≥ 60 kg N/ha (≥ 2½ bags urea), use more splits for longer duration cultivars (> 120 DAS).
- Do not apply more than 30–35 kg N/ha (1½ bags urea) in a single dose (split) to minimize losses.
- In areas where acidity is high (pH > 4.8), do NOT use Sulphate of Ammonia if urea is unavailable. This will avoid further soil acidification.
- Give basal N only when necessary, Note: in soils with high mineral N releasing potential, e.g. savannah soils, basal N may not be necessary.
- Use IRRI Leaf Color Chart (LCC), when available, to guide in topdressing.

Topdressing N with straight fertilizers (e.g. urea)

To topdress the recommended rate: 60–80 kg N/ha with urea.

- Use the moderate rate of 60 kg N/ha (2½ bags urea) for soil that is low to moderately fertile, i.e. that has recovered from fallow.
- Use the high rate of 80 kg N/ha (3½ bags urea) for poorly fertile soil. In extreme cases, higher rates of 100–120 kg N/ha (4–5 bags urea) may be used.
- For early to medium maturing cultivars, e.g. FARO 55 (NERICA1), topdress 60 kg N/ha from urea in two equal splits (30 kg N/ha).
- Weigh 65 kg (~1⅓ bags) urea and apply at onset of tillering (~21 days after seeding [DAS]) for first split, just after 1st weeding.
- Repeat with the same amount at about panicle initiation (when the rice is pregnant), e.g. between 45–50 DAS (FARO 55 [NERICA1]).

- Broadcast uniformly on the soil surface (best after 2nd weeding)
- Localized application: placing the fertilizer in small 2 cm deep grooves, 5 cm away from plant row and closing with soil will give the best result.

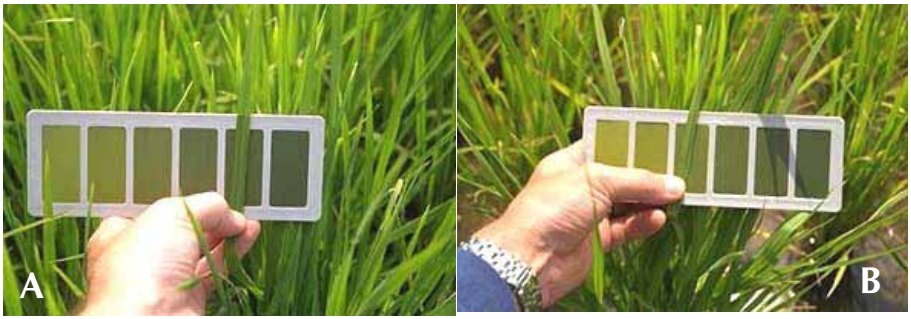
Use of color chart to guide nitrogen topdressing

- When a Leaf Color Chart (LCC) is available, it should be used to guide topdressing with urea when N deficiency (–N fertilizer below) is observed on the field.

N deficiency (–N fertilizer) and N sufficiency (+N fertilizer)

- Use LCC starting from the beginning of tillering (21 DAS) and take readings once every 7–10 days.
- Use the uppermost fully expanded leaf which best reflects the N status of rice. Compare the color of the middle portion of the leaf with the LCC. Take the readings of 10 leaves from randomly-selected hills in the field. If the color is $\geq$ 3, then topdressing is needed.

Caution: Because leaf color is affected by the sun, always shade the leaf being measured with your body. The same person should take the readings and at the same time of the day.



Use of LCC for N topdressing: (A) Topdressing is not needed because leaves have dark color; (B) Topdressing is needed because leaves have pale color

To correct for iron deficiency:

- When the seedlings turn yellow 1–2 weeks after emergence, they may be suffering from iron deficiency. The deficiency needs to be corrected because it could limit plant growth and depress yield.
- Spray 1% ferrous sulphate with 0.2% citric acid or lemon at 500 liters/ha once or twice (at 2-week intervals) depending on the recovery of plants.
- Apply iron chelates and urea in between rows at 25 kg/ha.

Iron deficiency symptoms

To correct for zinc deficiency:

- Zinc deficiency manifests mostly 3–4 weeks after seeding as small-scattered light yellow spots on the older leaves that later enlarge, coalesce and turn deep brown; the entire leaves become rusty-brown and dry out within a month. White lines may sometimes appear along the leaf midrib, starting from the 2nd or 3rd fully matured leaves. Patches of poorly-established hills may be seen in the field. When conditions are severe, tillering is decreased and may stop completely.
- Apply 25 kg/ha zinc sulphate (20% zinc) to the soil or
- Alternately, spray 1% zinc sulphate with 0.5% lime at 500 litres/ha to the base as symptoms are seen.

Zinc deficiency symptoms

Mixing fertilizers

- When it is required to apply two or more elements and the desired compound fertilizer is not available but the straight fertilizers are available, you may weigh and mix the fertilizers before application. This is particularly important for large mechanized rice farms.
- However, note that not all fertilizers are compatible for mixing. For example, if basal N is necessary and you need to apply N and P as basal, do not mix ammonium sulphate with rock phosphate, or urea with super-phosphate. The elements will react with one another and become less effective. The chart in Annex 2 can serve as a guide for mixing fertilizers for application to various crops, not only to rice.

Fertilizer calculations

Example:
Recommended rate: 80 kg N–30 kg $P_2 0_5$–30 kg $K_2 0$ per hectare.
Compound fertilizer available: NPK 20–10–10

Objective: to calculate the amount of NPK 20–10–10 + urea to get the recommended rate.

- In the recommended rate, there is less P and K than N. Therefore, we have to first start the calculation with P and K.
- Formula: quantity required (Q) = $\frac{R}{C} \times 100$

  R = Recommended rate; i.e. 30 kg $P_2 0_5$/ha
  C = Fertilizer grade; i.e. 10 for $P_2 0_5$
- Amount of fertilizer = Q = 30/10 kg × 100 = 300 kg
- Since for $K_2 0$, also R = 30 kg $K_2 0$, C = 10, it means that the amount of fertilizer = 300 kg
- Therefore, if you take 300 kg of 20–10–10, you will get 30 kg $P_2 0_5$ and 30 kg $K_2 0$. But how much N will you get?
- The amount of N in 300 kg (= Rate) of 20–10–10 NPK is:
  $R = (Q \times C)/100$
  $R = \frac{300 \text{ kg} \times 20}{100}$
- If 80 kg N is required and NPK supplies 60 kg N, the balance of 20 kg N will be supplied from urea.
  Amount of urea:
  46 kg N ≡ 100 kg urea

Therefore, 20 kg N ≡ $\frac{20}{46} \times 100 = 43.5$ kg

Amount of urea is 43.5 kg / ha

Summary: Apply 300 kg NPK 20–10–10 as basal at seeding and 43.5 kg (~1 bag) urea as topdressing at about panicle initiation.

Table 3. To recommended rate from R kg/ha of nutrient element to Bags of Fertilizer/ha

Straight/compound fertilizer	Factor to multiply by R kg/ha (bags)
Nitrogen (N) • Urea • Calcium Ammonium Nitrate (CAN) • Ammonium sulphate (AS) • 20:10:10 (N:P:K) • 15:15:15 (N:P:K)	 0.043 (e.g. 30 kg N/ha ≡ 0.043 × 30 = 1.3 bags/ha urea) 0.077 (e.g. 30 kg N/ha ≡ 0.077 × 30 = 2.3 bags/ha CAN) 0.1 (e.g. 30 kg N/ha ≡ 0.1 × 30 = 3 bags/ha AN) 0.1 (e.g. 30 kg N/ha ≡ 0.1 30 = 3 bags/ha 20-10-10) 0.133 (e.g. 30 kg N/ha ≡ 0.133 × 30 = 4 bags/ha 15-15-15)
Phosphorus (P_2O_5) • Single super-phosphate (SSP) • Triple super phosphate (TSP) • Diammonium phosphate (DAP) • 20:10:10 (N:P:K) • 15:15:15 (N:P:K)	 0.111 (e.g. 30 kg P_2O_5/ha ≡ 0.111×30 = 3.3 bags/ha (SSP) 0.044 (e.g. 30 kg P_2O_5/ha ≡ 0.044×3 = 1.3 bags/ha (TSP) 0.038 (e.g. 30 kg P_2O_5/ha ≡ 0.038×30 = 1 bag/ha (DAP) 0.2 (e.g. 30 kg P_2O_5/ha ≡ 0.2×30 = 6 bags/ha (20:10:10) 0.133 (e.g. 30 kg P_2O_5/ha ≡ 0.133×30 = 4 bags/ha (15:15:15)
Potassium (K_2O) • Muriate of potash (MOP) • Sulphate of potash (SOP) • 20:10:10 (N:P:K) • 15:15:15 (N:P:K)	 0.033 (e.g. 30 kg K_2O/ha ≡ 0.033×30 = 1 bag/ha (MOP) 0.04 (e.g. 30 kg K_2O/ha ≡ 0.04×30 = 1.2 bags/ha (SOP) 0.2 (e.g. 30 kg K_2O/ha ≡ 0.2×30 = 6 bags/ha (20:10:10) 0.133 (e.g. 30 kg K_2O/ha ≡ 0.133×30 = 4 bags/ha (15:15:15:)

Legume–rice rotation systems

- Growing rice after dual-purpose grain legumes in rotation can reduce the use of mineral fertilizer nitrogen, increase soil organic matter, and improve rice plant health because some of the legumes can control soil pests such as *Striga* (noxious parasitic weed) and nematodes.
- Promiscuous dual-purpose soybean can contribute fixed N to rice. Example, soybean cvs. TG×1440-1E and TG×1019-2EB can contribute at least 20 kg N/ha to rice grown after the legume depending on the soil conditions.

Promiscuous dual-purpose soybean

Upland rice

- Dual-purpose early maturing (75-day) cowpea cv. IT97-568-11 when grown very early in the season and the grains harvested with the residues ploughed into the soil before seeding extra-early maturing rice (e.g. NERICA8) can contribute as much as 26 kg N /ha to the rice.
- Some of these dual-purpose grain legumes are available at the International Institute of Tropical Agriculture (IITA), Ibadan for testing for their adaptation to the local conditions in upland rice-based systems.

80-day Farmer Cowpea

75-day Dual-purpose Cowpea

85-day NERICA8

Weed control

Hand weeding

- First weeding should be thorough and within 2 to 3 weeks after emergence, using a hoe instead of a cutlass (the earlier the first weeding is done the better).
- Second weeding should be done 6 to 7 weeks after emergence, before panicle initiation and second N topdressing, to minimize the effect of the weeding process on panicle initiation.
- Weed a third time if necessary.

Note: Hand weeding can be relatively ineffective, particularly for controlling many of the perennial weeds (e.g. *Cyperus* spp.)

Hand weeding

Chemical weed control

Pre-emergence:

- Apply Ronstar™ (oxadiazon) 25(EC) 2-3 days after sowing or just after seeding at the rate of 4–6 liters/ha.
- When weeds have grown in the field, spray Gramoxone™ (paraquat) at 2 liters/ha but not more than 24 hours after sowing.
- DO NOT spray Gramoxone™ after the germination of paddy seeds, to avoid killing the seedlings.

Chemical weed control

Post-emergence:

- Apply Ronstar™ (PL) at the rate of 5–6 liters/ha at 14 to 21 days after seeding.
- Use propanil (Stan™ F34), Tamarice™ or propanil-bentazon (Basagram™) 14 to 21 days after seeding, at the rate of 3 kg a.i. per hectare.
- With a knapsack sprayer, apply 220 cm^3 of propanil or Tamarice™, or 150 cm^3 Basagram™ in 6 liters of water.

Corn grass (*Rottboellia* spp.)

- Any resistant weed species or newly germinating weeds like corn grass – *Rottboellia cochinchinensis* – should be rogued and removed from the field.

Volume of water to mix herbicide

- Volume of water to spray per hectare (WHA) depends on the output of the spray nozzle, the walking speed of the person spraying, and the width of the area to be sprayed.
- For a knapsack sprayer with low to very low pressure nozzles, in general, WHA ranges between 400 and 500 liters per hectare.
- If the recommended herbicide rate is 4 liters ha^{-1} and a low to very low pressure knapsack sprayer with WHA of 400 liters per hectare is to be used for spraying the herbicide, the concentration of the herbicide can be calculated thus:

  Concentration (C) $= 4 \times 1000\ cm^3/400$ liters
  $= 10\ cm^3$/liter
- If the size of the knapsack sprayer is 15 liters, then the quantity of herbicide is 10 cm^3/liters $\times$ 15 liters $= 150\ cm^3$.
- Therefore, take a graduated bottle or a cylinder marked at 150 cm^3. Pour in 150 cm^3 of the herbicide, and transfer into the sprayer, and fill the sprayer with water to the 15-liters mark, while stirring with a rod.

Table 4. Names and rates for herbicides used in controlling weeds in rice

COMMON HERBICIDES USED IN RICE	GROWTH STAGE OF RICE	GROWTH STAGE OF WEEDS	RATES		WEEDS CONTROLLED	SOME RESISTANT WEEDS
			Active ingredient (a.i.) (kg/ha)	Commercial product (liter/ha)		
PARAQUAT	After land preparation and just before rice seeding	Seedling stage to full development	0.6	3	Most broadleaves	Imperata, Cynodon dactylon, Cyperus
GLYPHOSATE	After land preparation and 2–3 weeks before rice seeding	Seedling stage to full development	2	6	Most weeds comprising sedges and grasses with rhizomes	None
OXADIAZON	Post rice seeding and pré-emergence (0–2 days) after seeding	Pre-emergence	1	4	Grasses, sedges, broadleaves	Composea, commelinacea, papilionacea and grasses with rhizomes
OXADIAZON	Post rice seeding (3 weeks after seeding)	3 to 4 leaves	0.5	2	Grasses, sedges, broadleaves	Composea, commelinacea, papilionacea and grasses with rhizomes
OXADIAZON+PROPANIL	10–15 days after rice seeding (plantlets emergence)	3 to 4 leaves	0.5+1.5	5	Grasses, sedges, broadleaves	Most weeds if 3–4 leaves stage is over
BENTAZON+PROPANIL	10–15 days after rice seeding (plantlets emergence)	3 to 4 leaves	0.9+1.5	6	Grasses, sedges, broadleaves	Most weeds if 3–4 leaves stage is over
FLUORFEN+PROPANIL	10–15 days after rice seeding (seedling emergence)	3 to 4 leaves	1.2+1.8	10	Grasses, sedges, broadleaves	Most weeds if 3–4 leaves stage is over
BENTHIOCARB+PROPANIL	10–15 days after rice seeding (seedling emergence)	3 to 4 leaves	0.9+1.7	8	Grasses, sedges, broadleaves	Most weeds if 3–4 leaves stage is over Pests control

Pest and disease control

Disease control (blast, brown spot, grain discoloration)

- Use disease resistant/tolerant varieties to Blast
- Use good cultural practices to limit blast infection.
  - High nitrogen associated with low potassium increase blast damage
  - Split application of nitrogen is better than one application to reduce blast damage
- Use clean healthy seeds
- Treat the seeds 1–2 days before planting to control seed-borne pathogens

- In case (and only in case) of being in an area condicive to fungal diseases, spray Dithane™ M-45 (80% of mancozeb) at 1.0 kg or Benlate™ (50% of benomyl) at 1.5 kg a.i/ha, in 500 liters of water to control rice blast, brown spot and grain discoloration. If the damage is severe, spray again after 15 days.

Insect control

Stem borers (*Sesamia, Chilo and Maliarpha species*)

Control


Stem borer

- Management of stubble by burning, plowing and flooding after harvest destroys diapausing larvae of *Maliarpha separatella*.
- Strip- and inter-cropping of maize with NERICA rice was found to be effective in reducing stem borer damage on rice because maize and rice share some common stemborer species.
- Insects such as Carabids, reduviids, dragonflies and spiders are known natural enemies (predators) of *Chilo zacconius* and should not be killed.
- The braconids (*Rhaconotus scirpophagae*, *Bracon antennatus*, and *Cotesia* (=*Apanteles*) *sesamiae*), and the eulophid (*Pediobus furvus*) are also natural enemies (gregarious endoparasitoids) of *Maliarpha separatella* and *Sesamia* spp. in Nigeria and should be protected in the field.
- Use of resistant/tolerant rice varieties such as LAC 23, ITA 121, TOS 4153, NERICA1, NERICA2, NERICA4, NERICA5, and NERICA7.

Termites

Control

- Effective traditional practices against termites include: use of bamboo stems, smoking the termite nest, use of salt, and flooding of termite nests with water.

Termites

- Biopesticides such as neem seed oil and neem powder (22 liters of neem seed oil concentrate in 220 liters of water/ha and 800 kg/ha, respectively) and powdered tobacco are effective against termites because they serve as potential replacement for persistent chemical pesticides, such as Carbofuran which has already been banned in several countries.
- The entomopathogenic fungus *Metarrhizium anisopliae* is an effective biological control strategy against termite attack on upland rice (2 grams spore powder of *Metarrhizium* mixed with 60 cm^3 of wood powder or saw dust. Put mixture in a hole of 3 cm depth and cover with a small quantity of saw dust to protect spores against sunlight).
- Application of red palm oil mixed with pawpaw is an indigenous biological control practice. The mixture attracts soldier ants that attack and drive away the termites.
- Use of resistant/tolerant rice varieties such as LAC 23, NERICA1, 2, 5, 14 and others.

Bird control

- Erect scarecrows randomly in the field.
- Scare the birds manually.
- Tie old VHS tapes diagonally across and around the field.
- Install bird nets if available.
- Use catapults.
- Discourage birds from breeding by cutting nearby trees, tall grasses, and destroying roosting sites.

Scarecrow

Rodent control

- Leave an uncropped margin of 1-2 meters around the field. Distribute poison (bait) mixed with maize, sorghum, millet or rice in bamboo boxes or containers in the uncropped margins and alleys.
- Fencing with bamboo or chicken wire mesh, or polythene sheet round the field may deter rats and grasscutters.
- Use of local metal traps.

Rodent

Rogueing

From heading until harvest, inspect field, remove and destroy off-type plants and weeds. The off-types can be identified through differences in:

- height
- growth cycle
- grain color
- grain shape
- panicle shape
- leaf shape
- leaf base color
- awnness

Removing off-type plants

Harvesting

- The crop is ready for harvest when the grains are hard and are turning yellow/brown. That is about 30–45 days after flowering or a month after 50% flowering

Harvesting matured rice

- Cut the stems with a sickle about 10–15 cm above the ground
- Lay harvested rice crop in upright position for drying before threshing.

Threshing

- Thresh immediately after harvesting to avoid losses.
- Use whacking frames or mechanical devices, but avoid threshing on bare floor to prevent the introduction of sand, pebbles and other foreign matter.
- Thresh on a mat or tarpaulin over concrete floor by flailing (i.e. beating rice against the floor, or against a stick or drum).
- Thresh carefully and avoid dehusking the grains.

Mechanical threshing of rice

Winnowing

- Winnow to separate the chaff and empty grains from the well-filled matured grains. Remove foreign matter in the paddy to avoid localized heating spots during parboiling.

Mechanical winnowing of paddy rice

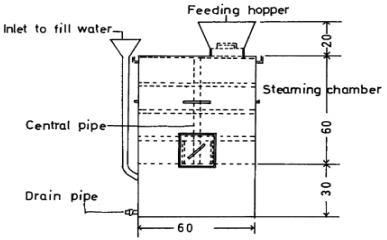
Drying

- Dry paddy properly to a safe moisture content of 13–14% by spreading in a thin layer (2–3 cm thick) on clean concrete floors, mats or tarpaulins and turning over periodically.
- Sun-dry slowly for 2–3 days to reduce breakage during milling.
- On a clear bright day, sun-dry for one day (about 9–10 hrs) only by spreading paddy thinly on clean concrete floors, mats or tarpaulin.

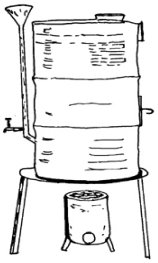
Sun-drying paddy on concrete floor

- Caution: avoid drying on bare floors or roadside, the main source of contamination with sand pebbles, stones and other foreign matter that can reduce the quality of rice
- Use a mechanical drier if available.

Parboiling



All dimensions in mm



Parboiling unit

- Parboiled rice has the advantages of better storage, cooking quality, being richer in food value, devoid of unpleasant odor and breaking less during milling.
- Soak paddy in hot water at 70°C (hot enough for your fingers to withstand the heat for about two seconds) for 5 to 6 hours.
- Discard all floating empty grains.
- Parboil rice by steaming soaked paddy in a jute bag for 10 to 16 minutes.
- Suspend the bag over steaming water in a drum.
- Stop parboiling when rice husks start to split open.
- Chalky grains or white centers indicate incomplete parboiling, which may cause breakage of grains during milling.
- Parboiling can be done in earthen pots or empty petrol drums depending on the quantity of rice.
- Note: steaming dexterises the kernels and drives the vitamin thiamine and other water-soluble nutrients from the testa or seed coat into the starchy core.

Milling

- Milling is the process of removing the husk or hull from the grain and the bran (pericarp, testa and aleurone layer) from the kernel (brown rice).
- Greater efficiency in the milling process results in whole grains with minimal broken grains to attract premium prices.
- Mill rice in a two-stage milling machine.
- Always mill one pure variety at a time.

Rice milling machine

Storage

- Where it is not possible to parboil, the paddy should be taken to the market as early as possible to avoid losses in storage.
- After parboiling, store when thoroughly dry in clean, dry grain stores.
- Store parboiled or milled rice in jute or sisal bags or polybags. Stack bags on wood raised from the floor in an air-tight room free from rodents and roof leakage.

Milled rice stored in sacks

Storage conditions

Good storage practices include:

- Store at 65% relative humidity.
- Store rice at a temperature within 10° F (5.5°C) of the average monthly air temperature and below 60°F (15.6°C) as long as possible during the year.
- Design and operate aeration system to maintain uniform rice moisture and temperature.
- Store only well cleaned rice.
- Inspect rice regularly (weekly) during storage.

Control of storage insect pests of rice

- Use dried chilli pepper to keep pests away.
- Use tolerant rice varieties such as NERICA4 and WAB 56-104
- Apply 2 tablets of phostoxin® a.i. aluminium phosphide in an unsealed envelope per 50 kg bag of rice grains. Phosphine gas is highly toxic and should not come in direct contact with the rice grains. Wear protective gloves and nose masks when handling.
- Treat seeds/grains with activated silica gel powder to dehydrate possible insects in the bulk.
- Store of grains at extremely low temperatures (-15 to -20°C) for minimum of 12 hours or high temperatures (above 55°C) for minimum of 3-4 hours.
- Use of airtight containers for grain storage.

Rice weevil – Sitophilus oryzae

Lesser grain borer – Rhizopertha dominica

Further reading

Dobermann, A. and T. Fairhurst. 2000. Rice: nutrient disorders and nutrient management. IRRI, Los Baños, (The Philippines).

Aduayi, E. A., V. O. Chude, B. A. Adebusuyi and S. O. Olayiwola. 2002. Fertilizer use and management practices for crops in Nigeria, 3rd ed. Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.

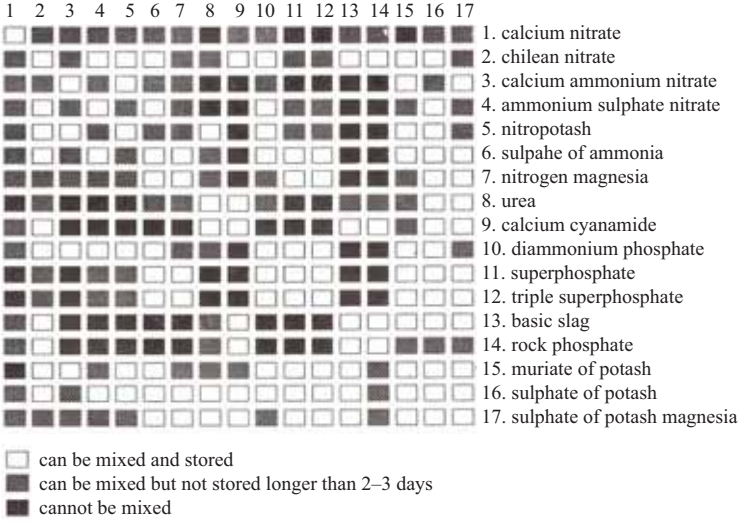
NSPFS. 2002. Fertilizers and their use: A pocket guide for extension officers. National Special Program on Food Security, Abuja, Nigeria.

NSPFS. 2004. Handbook on Soil test-based fertilizer recommendations for extension workers. Federal Department of Agricultural Land Resources and National Special Program on Food Security, Abuja, Nigeria.

Annex 1
Common fertilizers

Fertilizer		Nutrient
AN	Ammonium nitrate	33–34% N
ANL	Ammonium nitrate-limestone mixture (see CAN)	
AS	Ammonium sulfate	21% N
ASN	Ammonium sulfate nitrate	26% N
CN	Calcium nitrate	15% N
CAN	Ammonium nitrate/calcium carbonate mixture (may contain chalk, marl, dolomite, limestone, or chemically-precipitated calcium carbonate. Also called calcium ammonium nitrate and ammonium nitrate limestone (ANL)	20–28% N
UAN	Urea ammonium nitrate (solution)	28–32% N
APN	Ammonium phosphate nitrate	30-0-0 to 18-36-0
APS	Ammonium phosphate sulfate	16-20-0
DAP	Diammonium phosphate	18-46-0
MAP	Monoammonium phosphate	11-55-0
APP	Ammonium polyphosphate (solution)	10-34-0
NK	Nitrate of potash (potassium nitrate)	13-0-44
MOP	Muriate of potash (fertilizer-grade) potassium chloride	60–62% K_2O
SOP	Sulfate of potash (fertilizer-grade) potassium sulfate	50% K_2O
SSP	Single superphosphate	16–22% P_2O_5
TSP	Triple superphosphate	44–48% P_2O_5
KMP	Potassium metaphosphate	0-55-37
MKP	Monopotassium phosphate	0-47-31

Annex 2
Guide for mixing straight fertilizers



Pesticide safety

Pesticides can be highly poisonous and it is therefore important to take adequate safety precautions when transporting, storing or handling agricultural and other pesticides. Misuse of pesticides and other chemicals used in agriculture is responsible for many serious injuries and deaths in rural areas each year.

Always read and follow thoroughly the instructions printed on the pesticide label. Do not remove the label from the containers or boxes. Make sure that the chemical you want to use is still permitted for use in your country. Do not mix agrochemicals unless you have clear label guidance that the chemicals are compatible.

Always wear suitable protective clothing. Rubber gloves, overalls, a face mask and respirator are recommended when mixing pesticides. Gloves, long trousers and a long-sleeved shirt should be worn when applying less hazardous pesticides. This clothing can be uncomfortable to wear in humid climates but it is important that pesticides are not allowed to enter the body through the skin, mouth or lungs. Keep and wash this clothing separately from other garments.

Handle pesticides with care. Inspect pesticide containers for leaks before handling them. Avoid splashing or spilling liquids and causing powders to puff up or be spilled. Avoid inhaling dusts or vapors. Never work alone when handling the more toxic pesticides. Do not re-enter the treated area until the spray is dry or the specified re-entry time on the label has elapsed. In case of injury or accidental swallowing etc., go immediately to the nearest health center or infirmary with the box or container for the chemical.

Antidote: Make sure you know the antidote of the chemical you are using so that it can be used in case of accidental intoxication.

Never eat, smoke or drink when handling pesticides. Always wash thoroughly with soap and water after handling agrochemicals. If possible, have a container of water readily to hand for emergency wash use.

Only use pesticides when the weather is still and dry. Read the label for appropriate instructions. Do not use agrochemicals designed for a particular crop, e.g. cotton, on another unrelated crop such as cabbage or onion. Nor should crop pesticides be used to treat animals.

Keep an accurate record of pesticide usage, including quantity used, rate and date of application.

Storage: Store pesticides in a building or storage area reserved solely for this purpose and which can be securely locked. Keep pesticides in a store which is not likely to flood and is well away from food, feed and water supplies. Prevent unauthorized people, especially children, from having access to or contact with pesticides. Store pesticides in the original labeled container and protect the labels in storage so that they remain readable. Store large quantities of herbicides in a separate building or area from other pesticides.

Management of leftover agrochemicals: Always try to prepare only the quantity that is needed for the area to be treated so as to avoid having small quantities left over. These are difficult to keep or dispose of safely. The remaining chemicals, no matter how much or how little they are, should never be thrown away behind the store or in a nearby stream or bush. They should not be transferred to improper containers such as an empty food, feed, medicine or beverage container nor misplaced, but must be securely kept in the store in the original container or box until they can be used or disposed of safely. Small quantities of chemicals can be added to your next spray tank in the correct quantities. Washings from used chemical containers can also be added to the spray tank.

Transportation: Transport pesticides in an upright position in the open box of a truck, securing all containers. Do not transport pesticides in the passenger area of any vehicle. Do not allow anyone to ride in the back with the pesticides.

Disposal of pesticide containers: Rinse all pesticide containers three times prior to disposal to reduce environmental contamination. Puncture or break the used containers before taking them to a designated pesticide containers disposal site. Do not throw empty pesticide containers carelessly about the farm or into rivers. Where there is no designated pesticide containers disposal site, such containers should be buried deeply in a properly labeled area that is far from water sources.

Notes

About the Consultative Group on International Agricultural Research (CGIAR)

The Consultative Group on International Agricultural Research (CGIAR), established in 1971, is a strategic partnership of countries, international and regional organizations and private foundations supporting the work of 15 international Centers. In collaboration with national agricultural research systems, civil society and the private sector, the CGIAR fosters sustainable agricultural growth through high-quality science aimed at benefiting the poor through stronger food security, better human nutrition and health, higher incomes and improved management of natural resources.

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CGIAR Centers

CIAT	Centro Internaçional de Agricultura Tropical (Cali, Colombia)
CIFOR	Center for International Forestry Research (Bogor, Indonesia)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico, DF, Mexico)
CIP	Centro Internaçional de la Papa (Lima, Peru)
ICARDA	International Center for Agricultural Research in the Dry Areas (Aleppo, Syria)
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ICRAF	World Agroforestry Centre (Nairobi, Kenya)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (Patencheru, India)
IFPRI	International Food Policy Research Institute (Washington, D.C., USA)
IITA	International Institute of Tropical Agriculture (Ibadan, Nigeria)
ILRI	International Livestock Research Institute (Nairobi, Kenya)
IPGRI	International Plant Genetic Resources Institute (Rome, Italy)
IRRI	International Rice Research Institute (Los Baños, Philippines)
IWMI	International Water Management Institute (Colombo, Sri Lanka)
WARDA	Africa Rice Center (Cotonou, Benin)

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