Oryza Sativa L.

Monograph

Agricultural Science 2017-2018

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1.0 Introduction

Rice, *Oryza Sativa* has been feeding the world for over 5,000 years. More than 40,000 varieties of rice grow across every continent except Antarctica. It is one of the most planted crops on Earth and one of the cheapest too. In Colombia, white rice is fundamental for every dish of the day; in India it gets associated with prosperity and with the Hindu goddess of wealth, Lakshmi. In Burma the average person consumes about 500 pounds of rice a year.

This monograph sets out to provide the reader an introduction to rice, its biology, its needs, how it grows and how it is managed and how it is traded across the globe, in its many forms.

The ecological requirements for rice, its origin and family contexts are described in chapter two. Chapter three describes its biology, life cycle, and interactions it has with other plants and animals. Propagation and management is covered in chapter 4; this chapter gives details how to grow and manage rice. Finally, the fifth chapter briefly touches on world trade in rice, other products that can be produced from rice and future products.

2.0 Ecology

2.1 Distributional Context

2.1.1 Affinities

Rice is the seed of the grass species *Oryza sativa* (Figure 1) recognized as Asian rice or *Oryza glaberrima* known as African rice. It is the plant species usually referred to in English as rice.

The Oryza family is believed to have originated about 14 million years ago in what is now SouthEast Asia and the Philippines. Since then, it has evolved and diversified into wild “Oryza species” which are now distributed throughout the tropics. (Ricepedia, 2014)

Figure 1: Oryza Family

2.1.3 Origin

Rice has been around on earth's history for a very long time. In fact, it is said that its origins seem to start in the time when continents were stuck together and were known as Pangaea and Gondwanaland. Some archaeologists infer this information from the fact that very old varieties are found in different parts of the world, which did not have contact with each other. However, The exact origin of rice has not been fully discovered yet. Archaeologists have concluded the earliest use of rice to at least 10 000 BC, and its earliest cultivation to around 7000 BC - 4000 BC. At the current moment, we do not know when it was first discovered or domesticated. (All India Rice Exporters Association, 2012)

Oryza Sativa is not a tropical plant but is still associated with a wet, humid climate. It is generally believed that the domestication of the plant began in the Asian arc. According to schools of thought, rice is probably some sort of evolution of a wild grass that was cultivated in the foothills of the Eastern Himalayas and the upper tracts of the Irrawaddy and Mekong river basins, Figure 1 (below)(All India Rice Exporters Association, 2012). "The Persians are known to have been importers of the grain. From there its use spreaded to Mesopotamia and Turkestan. It is believed that when Alexander the Great invaded India in 327 B.C, one of the prized possessions he carried back with him was rice" .(All India Rice Exporters Association, 2012)

Figure 2: Asian Arc with Irrawaddy and Mekong Rivers highlighted

2.1.4 Present Distribution

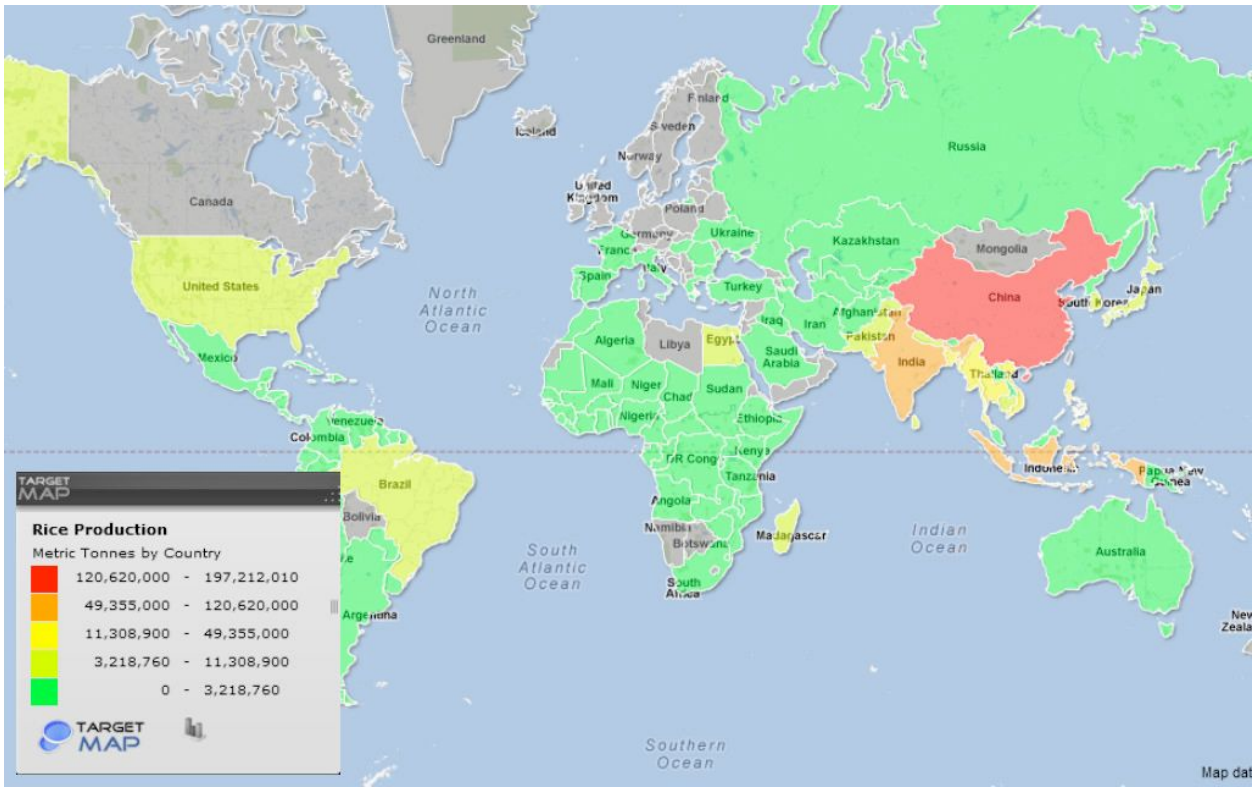

Figure 3: Rice production quantities

Oryza sativa is one a few plants that are produced in all of the seven continents of the world. China being the biggest rice producer with over 197,212,010 metric tones of the plant all over the country, followed by India with 120,620,000 metric tonnes and third Indonesia with 66,411,500 metric tonnes. (“2010 World Rice Production,” 2010)

The price of rice is a key variable for farmers, consumers, and governments in most of Asia, and in many other parts of the world. Although the world market price of rice has declined over time, domestic prices are more relevant for farmers and consumers.

There is big constant change on the domestic price of rice throughout the different countries of the world. Some countries like Japan, Korea, Turkmenistan, or Brunei have extraordinarily high domestic prices that are at least seven times the median price of $239 per ton. “Higher GDP per

capita and higher proportions of imports in domestic consumption are both associated with higher domestic prices."(Ricepedia, 2014)

2.2 Environmental factors and distribution

2.2.1 Elevation

Rice can be grown from sea level all over to high altitudes. Altitude may affect the plant growing process depending on how the crop is planted and where is planted.

Rainfed upland rice is for example grown like wheat or maize, "in mixed farming systems without irrigation and without puddling. The ecosystem is extremely diverse, including fields that are level, gently rolling or steep, at altitudes up to 2,000 meters and with rainfall ranging from 1,000 to 4,500 mm annually." (Ricepedia, 2014) For an agriculturist who works with rice, altitude is not as an important factor to worry about. Rice has the ability to grow in different environments and elevations, still as explained, this can vary the plant's development.

Figure 4. Rice paddies

2.2.2 Climate

Most people look at rice as a wetland plant which crops grow in deep pools of water commonly known as paddies, and this is certainly the most common form of planting. Still, there are also other types that grow on dry land, and others that can handle almost a total submergence under water. Rice is ideally adapted to tropical and subtropical conditions marked by heavy seasonal rainfall. It will grow to a maximum of 45 degrees north of the equator, which pretty much explains why it is today cultivated on every continent except Antarctica (Morgenstern, 2010) Even though it is a tropical climate crop it can still grow successfully in humid to sub-humid regions under subtropical and temperate climate. (Kumar, 2013)

Figure 5.

2.2.3 Geology and soils

The most important thing about rice paddy is that it can hold the big amount of water needed, this is why the soil beneath the crop has to count with certain necessary characteristics. Ideally, soil needs to include about 50% clay content. Rice can be cultivated in almost all types of soils

with varying productivity. Under high temperature, high humidity with sufficient rainfall and irrigation facilities, rice can be grown in any type of soil. Today, the major soil groups in which rice crops are grown are riverine alluvium, red-yellow, red loamy, hill and sub-montane, Terai, laterite, coastal alluvium, red sandy, mixed red and black and medium and shallow black soils. (Kumar, 2013)

For a rainfed upland rice plant soils range from highly fertile to highly weathered, infertile and acidic, but only 15 percent of total upland rice grows where soils are fertile and the growing season is long.(Ricepedia, 2014)

Riverine alluvium Red-yellow Red loamy

Figure 6: Different types of soil that *O. sativa* can be grown in. (SOURCES OF PHOTOS)

2.2.4 Toposequences

Rice grows in a wide range of environments and is productive in many situations where other crops would fail. Most classifications of rice environments are based on altitude (upland vs. lowland) and water source (irrigated or rainfed). The rice plant can be grown at different land situations, but there are three standards that most people tend to follow when growing their rice crops. These are in Irrigated rice environments, Rainfed lowland environments and Rainfed upland environments.

Figure 7. Rainfed upland environment

2.3 Oriza Sativa as a vegetation component

2.3.1 Chorology and Vegetation

Oryza sativa contains two major subspecies: the sticky, short grain japonica or sinica,and the non-sticky, long-grained indica. Japonica varieties are usually cultivated in dry fields, in temperate East Asia, upland areas of Southeast Asia and high elevations in South Asia, while indica varieties are mainly lowland rices, grown mostly submerged, throughout tropical Asia. Recent genetic evidence show that all forms of Asian rice, both *indica* and *japonica*, come from a single domestication event that occurred 8,200–13,500 years ago in the Pearl River valley region of China. (Ricepedia, 2014)

Figure 8.

Japonica is a group of rice which is normally grown throughout northern and eastern China and in some other areas of the world. It is found in the colder zones of the subtropics and in the temperate zones. It is a short plant with dark green leaves and medium height tillers. Japonica grains are short and round, do not shatter easily and have low amylose content, making them moist and sticky when cooked.

The Japonica has a sub species called Tropical Japonica or Javanica. This type of plants are characterized by having tall, broad, stiff, light green leaves. The grains are long, broad, and thick, do not shatter easily, and have low amylose content.

And last the Indica plant, which are tall with broad to narrow, light green leaves. The grains are long to short, slender, somewhat flat, tend to shatter more easily and have high amylose content, making them drier and flakier when cooked than *japonica* varieties.(Ricepedia, 2014)

Figure 9.

2.3.2 Community composition

Oryza Sativa is a part of the grass family meaning it can grow with other grains and legume crops like wheat, corn or soybeans. Wheat being a great crop companion since their growth processes may be similar because both can grow in paddies and consume high amounts of water. (Taub, 2016)

2.3.3 Interactions involving Oriza Sativa within communities

Rice crops usually will have to lead with different predators including ants, some insect families as Carabidae, plant bugs, amphibians, dragonflies, and other beetles and water bugs; however, there are other animals who help the crops from getting diseases from other insects, the most important being spiders. “A spider can consume about 30 white leafhoppers in a day.” (Wopereis, 2009) One great characteristic of these spiders is that they never eat rice, and only feed on insects, whereas other insect predators feed both on rice and insects. Some of the

spider families that can be found in rice paddy fields are: Lycosidae, Thomisidae, Tetragnatidae, Araneidae and Pholcidae (Wopereis, 2009)



Dragonfly Tarnished Plant Bug Carabidae(Ground beetle)

Figure 10. Common Insect Rice Predators seen at crops



Tetragnatidae Lycosidae Pholcidae

Figure 11. Predator Spider Families

Xanthomonas oryzae pv. oryzae (Xoo), which causes a vascular disease in rice, on rice plants and consequent interactions with a rice herbivore, brown rice planthopper (BPH) Nilaparvata lugens, and its major predator, Cyrtorhinus lividipennis, were investigated. (Sun & Liu, 2016)

Table 1. The table above shows some of the most insects in rice cropping.

Name of damage	Order/Family/Species	Type of damage	Symptom description	Insect harmful stage	Susceptible plant stage	Impact on yield
Rice Yellow mottle virus (RYMV)	Coleoptera Locusts Cicadas	Leaf destruction Cut Leaves Perforation spots in lines	Early yellowing Stunting	Adults	Vegetative stage even when transplanted	Sometimes no yield at all
Onion tube	Fly (Rice Gall Midge)	No leaf destruction	Some leaves change into yellowy-white tubes looking like onion leaves	Larva (Small yellow worm)	Vegetative stage	Sometimes no yield at all
Dead heart	Red flies with black antennas: Diopsis Butterflies: Chilo, *Sesamia, Scirpophaga*	No leaf destruction	Some leaves change into yellowy-brown tubes called dead heart Plants can be pulled up easily	Larva (small yellow worm)	Early vegetative stage	High yield despite attack
Defoliation	Small white butterflies: Nymphula	Many leaf fragments floating on water: they are the sheaths/covers that protect the larvae	Tips of rice leaves are cut Field whitening	Larva	Early tillering	Rice fields usually recover without losses
Destruction of roots	Termites: Microtermes, Macrotermes	No tube formed No leaf destruction	Early yellowing and drying of leaves	Adult termites "workers"	Any time in cycle whenever water is lacking	Losses may be high
Grain blackening	Stinking bugs Aspavia /eptocoryza	Small black or brown spots on grains	Bad grain quality (color, fragrance, flavor)	Adults	Reproductive stage and maturity	Small scale indirect losses

3.0 Biology

3.1 Chromosome Complement

3.2 Life Cycle And Phenology

3.2.1 Life Cycle

According to the Global Rice Science Partnership, the Rice plant takes about 3 to 6 months to grow from seed to a mature plant depending on the variety and environmental conditions. Rice varieties can be categorized into two different groups: the short-duration varieties which mature in 105–120 days and the long-duration varieties which mature in about 150 days. All rice plants go through a process of three growth phases: vegetative, reproductive, and ripening. “A 120-day variety, when planted in a tropical environment, spends about 60 days in the vegetative phase, 30 days in the reproductive phase, and 30 days in the ripening phase”(Ricepedia, 2014)

The vegetative phase starts when the seed germinates into a seedling and ends at tillering.This phase is recognized by the development of tillers and more leaves, and a moderate increase in the height of the plant. The amount of time the vegetative phase takes depends on the variety of the rice specie, but is normally between 55 and 85 days.

According to Ricepedia (2014) information about the 3 phases, the best way to know that the oryza sativa is ready for the reproductive phase is noticing a bulging of the leaf stem that conceals the developing panicle, this part is known as the ‘booting’ stage. Afterwards the tip of the developing panicle appears from the stem and continues to grow. It is said that Rice is at its ‘heading’ stage when the panicle is fully visible once this has happened the plant flowering will begin.

The ripening phase begins as soon as flowering starts and finishes when the rain is “mature” enough to be harvested. The stage takes usually 30 days. “Rainy days or low temperatures may lengthen the ripening phase, while sunny and warm days may shorten it” (Ricepedia, 2014)

3.3 Reproductive Biology

3.3.1 Pollen

Once the rice plants has gotten to its ‘heading’ stage when the panicle is fully visible. Flowering begins one day after heading has completed. When the flowers open they spread their pollen onto each other so that pollination occurs. The Flowering process in this certain type of plant may be present for about 7 days.(Ricepedia, 2014)

Figure 12. Visible pollen coming out from the panicle

Figure 13. Anthers of rice. (Moldenhauer, 2016)

3.3.2 Sexuality

Orisa sativa's sexual reproduction step is the most important in increasing the genetic diversity of offspring. We can categorize it by two prime events: meiosis and fertilization. Meiosis is an important event to form haploid spores and gametes, and is recognized by a single round of premeiotic DNA replication followed by two continuous rounds of chromosome segregation. "Homologous recombination, an essential feature of meiosis, results in generating new haplotypes by shuffling alleles. Fertilization is achieved by the fusion of two gametes and produces new genotypes of diploid cell or zygote".(Dobzhansky 1951; Stebbins 1958) In contrast, the reproductive isolation contributes to establishing genetic stability of species, rather than genetic diversity, in most eukaryotes, and is achieved by various mechanisms, for example, the differential fitness of the gametophyte or zygote. Biological species are generally defined as groups of interbreeding populations that are reproductively isolated (Mayr 1942).

3.3.4 Anthesis

There are 4 steps in anthesis, and the whole process takes to one to two hours and a half to happen completely.

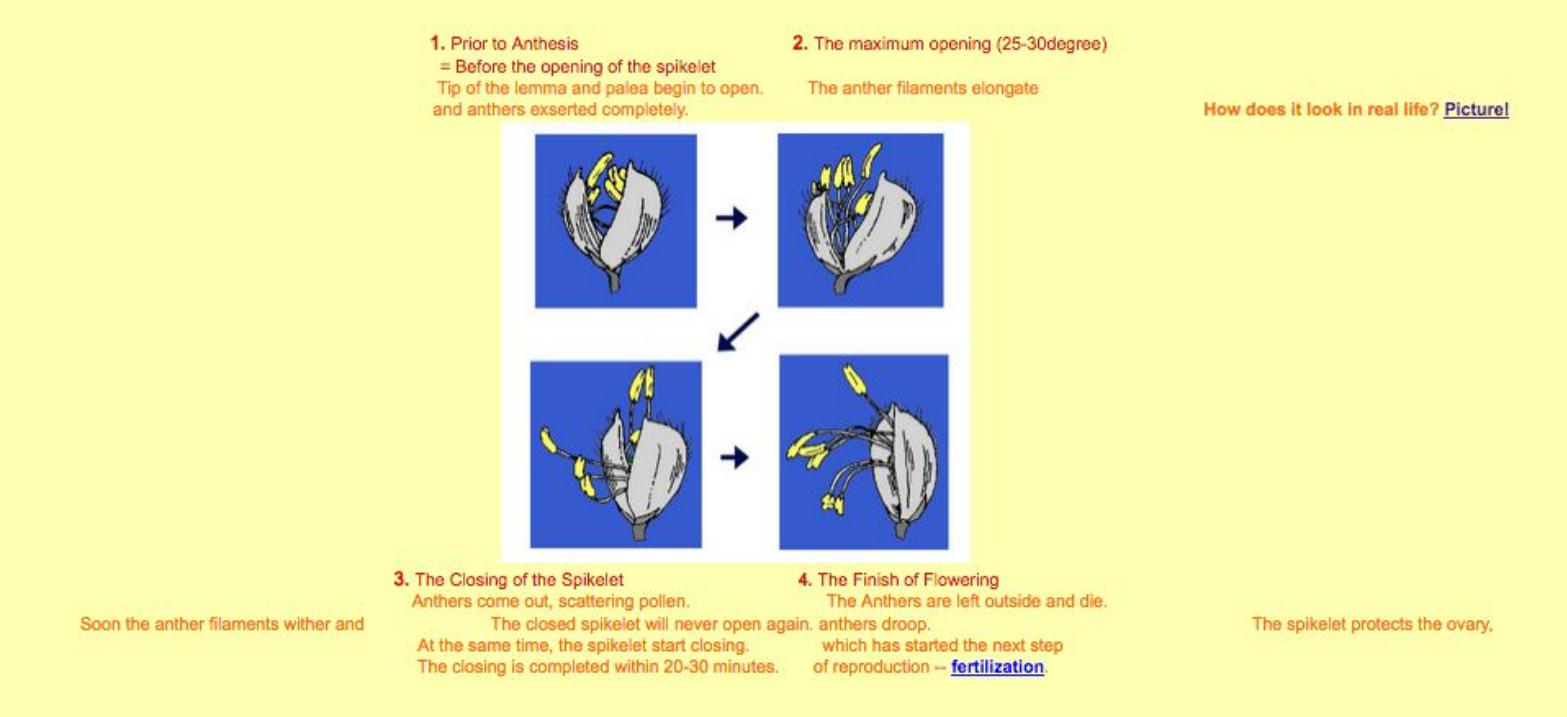

Figure 14. This chart shows the different 4 stages from the anthesis process. From the beginning (before the opening of the spikelet) to the end were flowering is finished and the anthers are left outside to die and start the next reproduction. (Rost, 1997)

Figure 15: Picture of the maximum opening stage in anthesis of rice.

3.3.4 Pollination and potential pollinators

3.3.5 Fruit Development

Depending on the type of rice crop, different amounts of time are needed to harvest the grain. According to the International Rice Research Institute (2015), long-duration varieties takes 160 days and longer (suitable for irrigated areas or flood-prone areas). Medium-duration varieties takes 120–140 days (suitable for both rainfed and irrigated áreas) and short-duration varieties take less than 120 days (suitable for drought-prone areas or for double cropping).

When harvesting comes, it is highly important to know when and how to take this process. A correct timing of harvest is necessary to prevent crop loss. Crop loss may happen by different causes such as rats, birds, lodging, insects, and shattering. Harvesting in the correct moment secures a good grain quality and high market value product. Getting to harvest the rice in early conditions will result in a collection of immature grains and harvesting in late conditions will ensure to an excessive loss and increased breakage in rice. As well as the physical product, harvesting time may also affect the germination potential of a rice seed. (Gummert, 2004)

There are multiples of getting to know the correct time to harvest the grains. “Generally, the perfect harvest time is between 130 and 136 days after sowing for late, 113 and 125 for medium, and 110 days for early-maturing varieties” (Rickman, 2004) But there are more ways to know when this process should be done. For example if the moisture content is between 20−25% (wet basis), and the grains are firm but not breakable when squeezed between teeth the crop should be ready for harvesting.

4.0 Propagation & Management

Figure 16: The steps in rice production.

4.1 Natural Regeneration

As any other grass species, the rice plant has the ability to regenerate naturally when dying(Gale, 1996). After dying it goes back to the ground at the end of the growing season and regenerates for the next season. By dropping the seed, this quickly builds up in the underground root systems.

4.2.1 Propagation from seed

Once the seeds are collected by crop farmers they may be infected with microbes that can generate different diseases on the seedling as well as in the crop. This can affect seed germination and can also be transmitted from seed to seedling to plant. That is why farmers

have come out with multiple seed treatments to prevent diseases and control seeds and soil. These treatments improve germination, vigor, and productivity. According to Gummert (2004) the following treatments can assist in improving:

- Seed Dormancy: Which consists in exposing the seeds to high temperatures like (40−42°C) for 1 or 2 days prior to sowing. Then soaking them for 4−8 hrs in water and re-dry prior to sowing. Seeds must be sown within 1−2 days after priming. Afterwards Pre-germinating by submerging seeds in water for 12−24 hrs or until small shoots appear at the end of the seed. In colder weather, seeds may need to be soaked for 36−48 hrs. Drain and dry the seed in bag for 24 hrs in a shady area where air can circulate around the bags. If bag temperatures exceed 42°C, some seeds will be damaged. Broadcast or drum seed before the roots exceed 5 mm in length. When calculating the planting rate, allow for expansion of 10-30% in seed weight. (Gummert, 2004)
- *Azospirillum*: This treatment consists in using 1 g of Azospirillum sp. inoculant (which comer in powder) per kg of seed and mix with primed wet seed just before sowing.

These treatments will help reduce the possibilities of the plants to get any air-borne diseases. (Gummert, 2004)

4.3 Planting

There are two different ways rice crops can be planted: transplanted or direct seeded.

In direct seeding, seeds are planted directly on the ground. In transplanting, seedlings are first planted in seed beds before they are planted in the field. The decision of whether to use one method or the other may depend on the following aspects: locality, type of soil, rice ecosystem, and availability of inputs and labor.

> *"Direct seeding requires 60−80 kg of seeds per ha, while transplanting only requires 40 kg per ha, at two plants per hill"* (Gummert, 2004)

4.4 Management

Choosing when to plant is essential before getting to do anything else on the fields. Choosing the right time to plant as well as having a well prepared seedbed will give a result of a fast growing, uniform crop that will have higher yields and better competition against any weeds and other pests that come in their way. The best considered time to plant depends on factors like: rice variety, locality, weather, water availability, and the best harvest time. Planting at the same time with other different crops within two weeks can help to minimize insects, diseases, birds, and rat pressure on individual fields. (Gummert, 2004)

4.4.1 Tending: pest and disease control

Once the crops are already planted and the rice plant is ready to grow, there must be a precise way to take control over any obstacles that limit *Oryza sativa's* growth development. Linus Regan is a studied agricultural business man who has planted rice and other grains for over 28 years. Regan has come out with various methods to overcome problems such as weeds, insects and diseases. He claims the major weed problems in many plantations such as rice are fall *Panicum spp*, sprangletop and yellow nutsedge weeds. For this kinds of weeds, Linus Regan highly recommends RebelEX herbicide, Clincher herbicide and Herbivore herbicides. (See 4.4.3 below.) He says:

> *"The earlier you get to manage weeds, the better, before they grow too much*." (Regan, 2018)

Figure 17. Fall Panicum

Figure 18.Sprangletop

Figure 19. Yellow Nutsedge

Water is run into the fields to a depth of only 5 inches. Consistent water depth has been shown to improve the rice plants' ability to compete against weeds for nutrients and sunlight, reducing the need for herbicides. Rice seed is then soaked and loaded into planes.

Flying at 100 mph, planes plant the fields from the air. The heavy seeds sink into the furrows and begin to grow.

If necessary, farmers may also treat the fields for the rice water weevil and other insects. Early application of just a few crop protection materials ensures pure rice at harvest.

4.4.2 Fruiting

Four to five-months is what usually takes rice seedlings to mature before the harvest.

When the rice grows to its maximum point (height of three feet) farmers have to be very careful to maintain the water depth at 5 inches. When the grain is totally ready to harvest, it begins to appear in long panicles on the top of the plant. On average, each acre of rice will yield over 8,000 pounds. (Bosworth, 2018)

Before harvesting, the fields must be fully drained. Once they're dry, experienced men or special machines (depending on crop sizes) should take the task of recollecting the grain since this should done very carefully due to quality reasons. These harvesters machines are designed to gently and fastly recollect the grain. During a big crop harvest, specialized tractors called bankout wagons get to the sides of the fields, and receive the rice and deliver it to trailers so the harvesters can continue on their task without having to stop to unload the product. (Bosworth, 2018)

Figure X

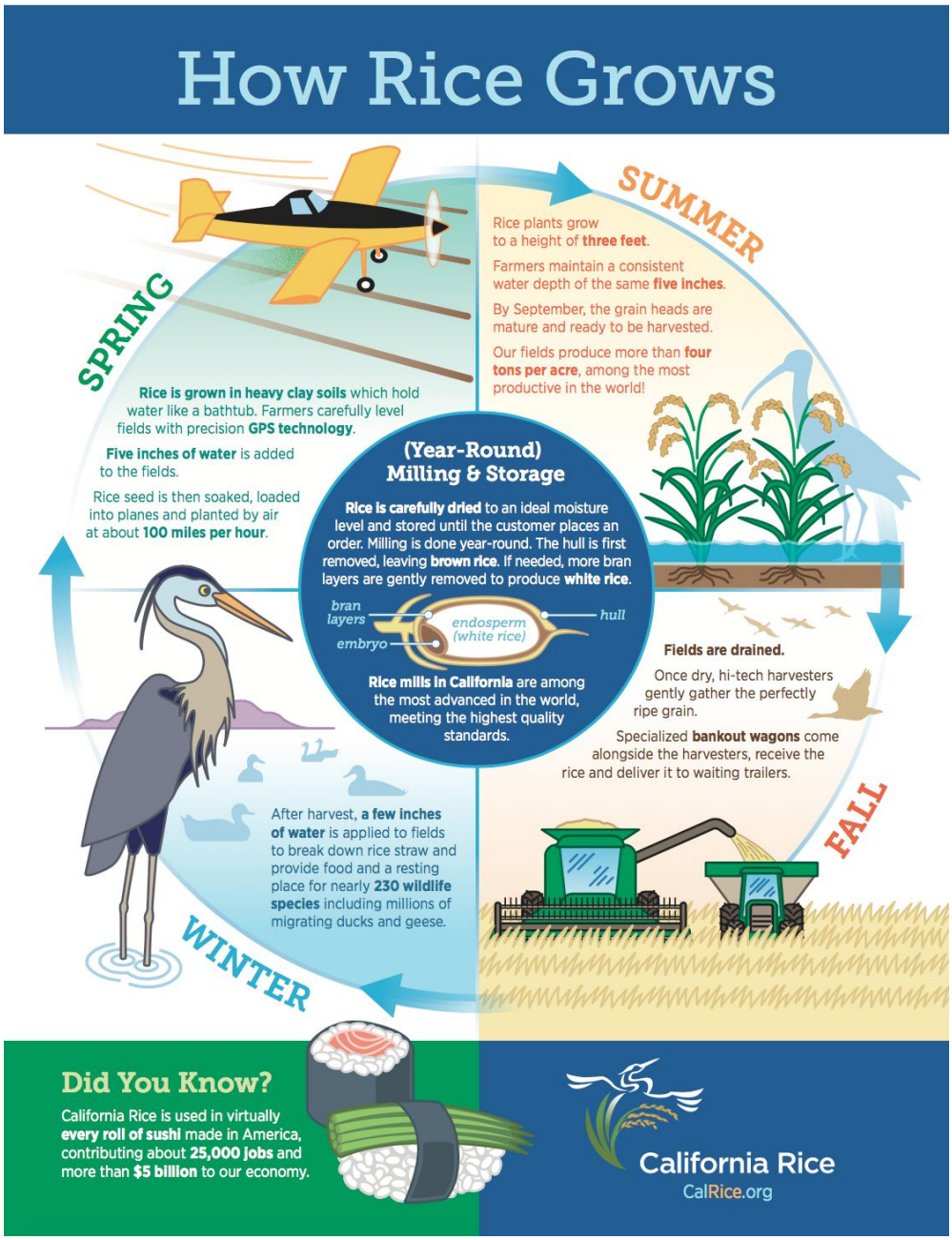

Figure 20. Cycle of Rice since beginning (Season Explanation) (Bosworth, 2018)

4.4.3 Pest and disease control

For the kinds of weeds that are common in this types of fields named above (fall panicum, sprangletop and yellow nutsedge), Linus Regan, highly recommends RebelEX herbicide, Clincher herbicide and Herbivore herbicides. He recommends: the earlier you get to manage weeds, the better, since this take a minimum amount of time to grow. (Regan, 2018)

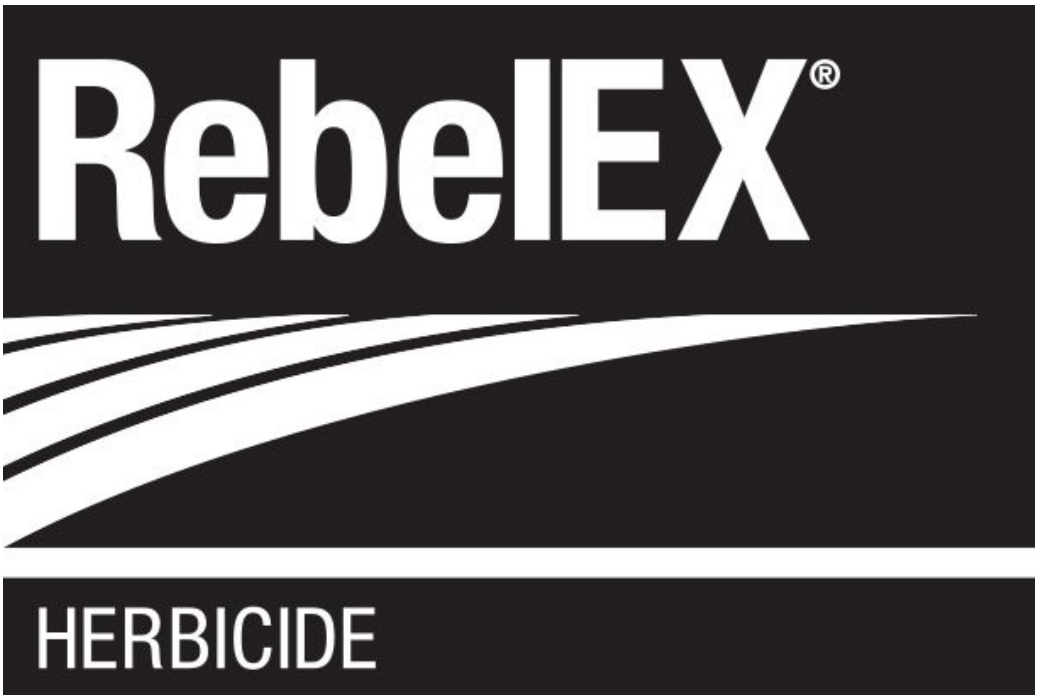

Figure 21. Rebel EX Herbicide

Figure 22. Clincher Herbicide

5.0 Marketing and Economy

5.1 Word Trade

5.1.1 Imports

The main countries that import rice are provided in Figure 23, below.

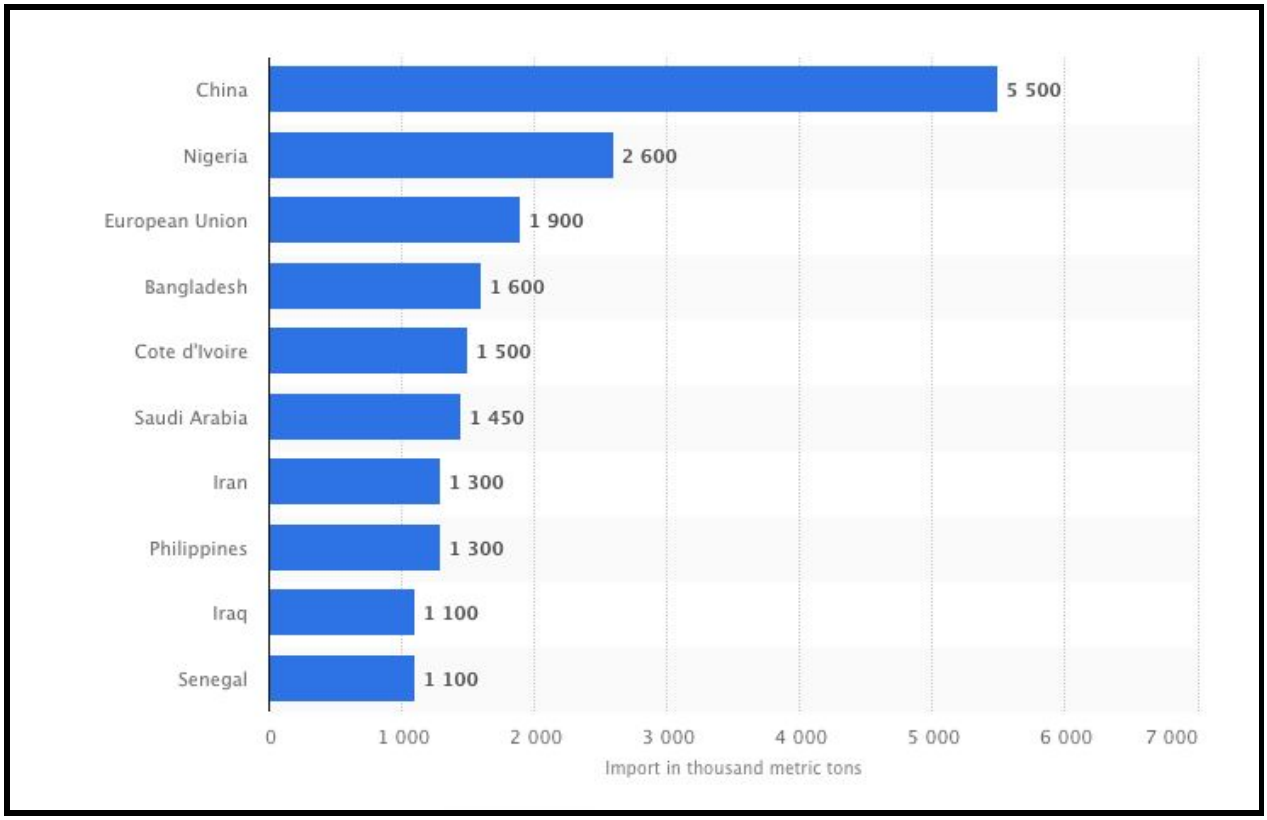

Figure 23. Major rice importers worldwide from 2017 to 2018 in 1,000 metric tons (Statista, 2018)

5.1.2 Exports

Table two below shows the countries that exported the highest dollar value worth of rice during 2016: (Workman, 2018)

Table 2. Worldwide exports of rice - 2016. (adapted from Workman, 2018).

Country	USD	% of total rice export
India	$5.3 billion	26.7
Thailand	$4.4 billion	21.9
United States	$1.9 billion	9.6
Pakistan	$1.7 Billion	8.5
Vietnam	$1.6 billion	8
Italy	$565.0 million	2.8
Myanmar (Burma)	$438.9 million	2.2
Uruguay	$413.8 million	2.1
China	$378.8 million	1.9
Cambodia	$305.9 million	1.5
Brazil	$251.9 million	1.3
Belgium	$241.8 million	1.2
Argentina	$212.5 million	1.1
Paraguay	$196 million	1
Guyana	$169 million	0.8

5.3 Products

5.3.1 Food Products

5.3.1.1 Basmati Rice

Basmati rice (Figure 24, below) is a very unique species of rice that origins from India and like every species of rice, it is available in white and brown versions. One of the first things you can notice when consuming this type of rice is its own unique, outstanding smell. According to George Mateljan:

"...this smell is due to the presence of a chemical called 2-acetyl-1-pyrroline, which is found in basmati rice at about 90 parts per billion. That's about 12 times more than in other types of rice, giving basmati its special aroma". (Mateljan, 2018).

Figure 24: A bowl of Basmati rice.

Both regular and basmati rice take about the same time to cook and they look very similar. Once cooked basmati rice becomes much longer, people describe it as a lighter and

more fluffy rice in comparison to the standard white rice and does not stick together. (Fayed, 2017)

5.3.1.2 Black Rice

Black rice (Figure 25, below) is much more different compared to the brown and white species. Its flavor is described as a nutty, earthy taste and it takes much longer to cook than white rice. It is high in fibre too (4.7 grams per 100 grams). According to Juliette Steen from the Huffington Post:

"Black rice also has a lower glycemic index, so it means if you've got diabetes it will be quite good as it's slow releasing" (Steen, 2016)

Figure 25: Black rice

5.3.1.4 Sweets

5.3.1.4.1 Rice Pudding

When cooking rice pudding there are multiple types of rice that may be used for this dessert. After researching different recipes I found many people use all kinds of different rice species and all of them work perfectly. The decision of what type rice to use for your rice pudding is completely personal depending on your taste. Dessert expert Cindy Mushet has organized this diagram to compare the four most common used types of rice for the pudding.

Figure 26: Different types of rice variety (Mushet, 2018)

5.3.2 Non Food products

5.3.2.1 Rice Husks

Rice hulls or rice husks are the hard protective covering that grows with rice. It is slightly larger than the rice grain, has a yellowish color and comes in a convex in shape. After harvesting rice crops, at the end there is always a very big amount of husks that get used to accomplish various features.

Figure 27: Rice husks.

Rice husk works very well as insulation material since it does not burn easily. This characteristic makes it highly resistant to moisture and fungal decomposition. It has also a high calorific value which makes it a good source of renewable energy. Rice husks may be used for making animal bedding as well as a building material. According to Jeffrey Windsor, Myanmar editor:

"The amorphous silica contained in rice husk ash helps to strengthen materials, and this is why there is a spiraling demand for it in the production of cement and concrete mixes, and low permeability concrete used for construction of bridges, nuclear plants, and in marine environments." (Windsor, 2016)

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