Food and Agriculture Organization of the United Nations

Good agricultural practices (GAP)

Rice/Paddy

(Oryza sativa)

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Abbreviations

ASEAN	Association of South East Asian Nations
BNF	biological nitrogen fixation
CA	conservation agriculture
CGIAR	Consultative Group on International Agricultural Research
CSA	climate-smart agriculture
DAP	diammonium phosphate
EM	effective microorganism
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field School
FYM	farmyard manure
GAP	good agricultural practices
ICM	integrated crop management
ICT	information and communications technology
ISO	International Organization for Standardization
IFDC	International Fertilizer Development Center
IPM	integrated pest management
ISBN	International Standard Book Number
MAP	ammonium acid phosphate
MOP	muriate of potash
NPK fertilizer	nitrogen phosphate potash fertilizer
PHI	pre-harvest interval
PPE	personal protective equipment
QC	quality control
SRI	System of Rice Intensification
SSP	single superphosphate
TSP	triple superphosphate
UDP	urea deep placement
USDA	United States Department of Agriculture

Executive summary

Rice plays an important role in Myanmar's agricultural economy, livelihoods, and food security. The country possesses favorable conditions to enhance rice productivity, quality, and export opportunities across the value chain. Achieving this involves improving farm-level productivity, processing practices, and overall rice competitiveness (Denning and Baroang, 2013). Effective strategies include adopting and expanding good agricultural practices (GAP) to enhance food safety and quality.

Small and resource-poor farmers can easily adopt GAP standards, which align with natural agroecosystems and indigenous knowledge. Techniques like organic manuring, integrated pest management (IPM), and climate-resilient crop varieties, alongside traditional rotation systems, are conducive to limited resource management. In order to satisfy consumer demands for safe, high-quality food and to ensure efficient and sustainable high-quality rice production, it is important to promote organized and project-guided marketing strategies and value chain development initiatives. These approaches will significantly contribute to supporting sustainable rice production and increasing the income of smallholder rice producers.

Under the Food and Agriculture Organization of the United Nations' Global Agriculture and Food Security Climate Friendly Agribusiness Value Chain (FAO-GAFSP-CFAVC) Programme, upgrading existing GAP based on Myanmar's and Association of South East Asian Nations's (ASEAN) standards is much needed. The upgraded GAP version for rice addresses food safety, produce quality, worker health, safety, and environmental management. Effective implementation and field level adoption will contribute to enhanced food safety, quality, ecological sustainability, and resource efficiency in rice production areas.

Gaps in knowledge, access, and efficiency of inputs and services for rice were identified through a comprehensive GAP situational analysis. Validation was achieved through research, discussions with market actors and stakeholders as well as insights from FAO experts, and extensive data research.

The objective of GAP dissemination involves a systematic, impact-oriented approach with stakeholder involvement. Context-specific information will be collected at the farmer's field. Capacity-building efforts involves lead farmer organizations, public-private partners, and value chain actors. The framework contains pre and post-harvest practices tailored for small and medium farmers, supported by farmer organizations, sensitization, technical assistance, and market linkages. On-farm demonstrations, farmer field schools, training, and information and communications technology (ICT) tools supplement GAP promotion. User-friendly IPM handbooks and Farmer Field School (FFS) curriculum complement the framework, guiding capacity-building efforts for farmers and GAP stakeholders to support and complement existing initiatives.

Glossary of good agricultural practices (GAP) terms

The following terminologies frequently used in compliance with GAP are important for their understanding, planning and implementation.

Term	Definition
Accreditation	The formal recognition by an independent body, generally known as an accreditation or certification body, that operates according to international standards.
Active ingredient	Ingredient of a plant protection product that is chemically and biologically active.
Aflatoxin	A toxic secondary metabolite produced by some fungi, especially *Aspergillus flavus* and *Aspergillus parasiticus*. Those commonly found in nature are B1, B2, G1 and G2 aflatoxins.
Assessment	An appraisal of procedures or operations based largely on experience and professional judgment.
Audit	The International Organization for Standardization (ISO) defines an audit as a systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent audit criteria are met.
Audit and inspection	A systematic, independent and document process for assessing compliance to GAP standards.
Audit evidence	All the information collected during the course of an audit, which serves as the basis for the auditor to make an opinion and determine compliance with the requirements (standard) being audited against. Such evidence includes records, factual statements and other verifiable information (e.g. observation of work activities and physical examination of products, materials and equipment) that is related to the audit criteria being used. There must be sufficient audit evidence for the auditor to submit a final opinion.
Biodiversity	The variability among living organisms from all sources, including 'inter alia' terrestrial, marine and other aquatic systems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
Broken kernels	Whose lengths are at least 2.5 parts of a whole kernel, but less than the length of head rice. This includes split kernels that retain less than 80 percent of the whole kernel.
Calibration	Determination of the accuracy of an instrument, usually by measurement of its variations from a standard, to ascertain the necessary correction factor.
Certification	The provision by an independent body of written assurance (a certificate) that the product, service or system in question meets specific requirements.
Certification body	A third-party auditing organization that audits facilities against a specific international standard or code.
Checklist	An inspection and audit tool with documented questions that reflect the requirements, procedures, or policies of an organization. For GAP inspections/audits it can be used by producers, producer groups, certification bodies or organizations (approved by GLOBALG.A.P. as appropriate) which help producers to implement GAP standards towards obtaining certification (or GLOBALG.A.P. certification).
Compliance Criteria (CC)	Information provided to further illustrate each control point and how to successfully address the requirement(s) identified in the control point.

Control Points (CP)	Each of the requirements requested by a standard (or GLOBALG.A.P. standards) to implement good agricultural practices. Within the GLOBALG.A.P. standards, control points are classified as Major Musts, Minor Musts, or Recommendations.
Control Points and Compliance Criteria (CPCC)	The comprehensive set of control points and compliance criteria that define the standard against which a producer's performance is measured both internally and externally.
Dry paddy rice	Paddy rice with the moisture of less than 15 percent for trade rice.
Dry season	The period of rice growing off rainy season.
Flowering date or blooming date	The day that not less than 80 percent of rice plants in the field are blooming.
Food safety	The assurance that food will not cause harm to the consumer when it is prepared and consumed according to its intended use.
Good agricultural practices (GAP)	Practices that address environmental, economic, and social sustainability for on-farm processes, resulting in safe and quality food and non-food agricultural products (FAO).
Hard rice	Broken kernel whose length is more than those of brokens but does not reach the length of the whole kernel. This includes split kernels that retain at least 80 percent of the whole kernel.
Hazard (as it relates to food safety):	A biological, chemical, or physical agent that could contaminate food at any stage and cause an unacceptable health risk.
Hazard (as related to GAP)	A biological, chemical, physical or any other property that may result in a situation that is unsafe for workers, consumers, or the environment.
Hazard Analysis Critical Control Point (HACCP)	A food safety system that identifies hazards, develops control points throughout the flow of food, sets critical limits, and monitors the effectiveness of these control measures.
Hazardous substances	Explosive substances such as flammable substances, oxidizing agents and peroxides, toxic substances, substances causing diseases, radioactive substances, mutagenic substances, corrosive substances, irritant substances; and other substances, either chemicals or anything which may cause harm to humans, animals, plants, properties or environments.
Hazardous/toxic	A substance or any article including chemicals, microorganisms or microbial toxins which may be harmful to human, animal, plant, property or environment.
Hygiene	Good practices that indicate conditions and measures for the production processes necessary to achieve a produce that is safe and suitable for consumption
Internal controls	The various engineered and managerial means -both formal and informal- established within an organization to help it direct and regulate its activities in order to achieve desired results; this also refers to the general methodology by which specific management processes are carried out within an organization.
Mature rice grain	Rice kernel that developed completely to ripening stage and is ready to be harvested. At least three quarters of the grain of the panicle turn yellow.
Milling quality of paddy	The amount of whole kernels and head rice obtained from a milling test calculated as percentage by weight of paddy.
Off-type rice	Rice plant of other varieties grown in the rice field but excluding weedy rice.
Pest	Any type of plant, animal or microorganism that causes damages to plants, plant produces and plant products.
Pesticide	A hazardous substance used in agriculture regulated by DoA in line with Pesticide Law (Pyidaungsu Hluttaw Law No. 14/2016)

Plot	An area in which a crop is planted and is not connected to other areas. In case the area is connected to others, the production management including inputs, cultural practices and personnel of the area, is clearly distinctive.
Quality Management System (QMS)	The organizational structure, procedures, processes and resources needed to implement quality management.
Record	A document containing objective evidence illustrating activities being performed and/or results achieved.
Red kernels	Rice kernels that have red bran layer covering the kernel wholly or partly.
Risk	The chance that a condition or set of conditions will lead to a hazard.
Risk assessment	An estimate of the probability, frequency and severity of the occurrence of a hazard.
Sample/sampling	Selecting a portion of a group of data in order to determine the accuracy or propriety or other characteristics of the whole body of data.
Self-asessment	Internal inspection of the production system and the registered product carried out by the producer or a sub-contractor, based on the GLOBALG.A.P. checklist (or checklist from another GAP scheme).
Standard	A document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose (ISO).
Traceability	The ability to retrace the history, use or location of a product (e.g. origin of materials, processes applied or distribution or placement after delivery) by means of recorded identification markers.
Verification	Confirmation by examination of evidence that a product, process or service fulfils specified requirements.
Visual inspection	An inspection of external appearances of an entity such as a produce, product or apparent environment condition. This is examined by eyes, but other sensory evaluation may be applied depending on the quality factors to be inspected. Additional tools such as a magnifying glass could also be used. Inspection of working procedure and process is also included.
Volunteer rice plant	Rice plant that germinated from those seeds remained in the field from the previous season.
Weedy rice	The weed, which has its plant and kernel similar to rice. The grain is normally shattered from its panicle before the harvest of rice.
Wet paddy rice	Paddy, which is harvested and immediately threshed without exposing to moisture reducing process. Normally the moisture of this paddy is not less than 18 percent by weight.
Wet season	The period of rice growing during rainy season.
Whole kernels	Rice kernels that are in whole condition without any broken parts, including kernels which have at least nine parts.
Worker	Any person or a farmer who has been contracted to carry out a task. This includes farm owners and managers, as well as family members carrying out tasks on the farm.

Source: Thomas Edmund. 2017. GAP Audit Training Manual.

CHAPTER 1 – INTRODUCTION

1.1. Scope of rice GAP

The GAP framework covers good agricultural practices required for rice production with ensuing food safety, produce quality, environmental management and safeguarding workers health and safety in line with Myanmar 2018 GAP guidelines, and ASEAN GAP recommended practices at the pre- and post-harvest crop management stages. The objective is to produce good quality, safe and suitable rice for consumption and processing taking into account inclusive good agricultural production and processing standards. The GAP standard is a comprehensive document introducing all the methods of rice cultivation. Regarding direct seeded rice (DSR) technology, about 49 percent monsoon rice and 78 percent summer rice are DSR in Myanmar. It is worthwhile to mention that GAP is primarily focused on the food safety aspects. To cater to the needs of rice production in different regions and agroecosystems, the GAP do not emphasize one specific rice production method in CDZ due to the variation of rice production systems in terms of season or sowing time, soil types and available resources. A system of rice intensification (SRI) is simply introduced as improved techniques, though general farmers are not yet adaptive to it due to intensive crop management and limited capacity of rice farmers. The method is an advanced technique and needs to be promoted in the future as a climate smart and climate resilient technique for rice cultivation.

1.2. Introduction

1.2.1. Origin and history of rice (*Oryza sativa*)

Rice is an important cereal crop and belongs to the Gramineae or grass family and genus *Oryza*, having twenty-one wild and two cultivated species. According to Oka (1960), *Oryza* species can be divided into three main groups, i.e. *O. sati*va and its relatives, *O. officinalis* and its relatives, and other more distantly related species. Domestication of wild rice(s) probably started about 9 000 years ago. The crop was developed as annual at various elevations in the eastern part of India, Northern Southeast Asia and Southwest China, and was subsequently improved by changing growth environment and drought temperature during the Neothermal age (10 000 to 15 000 years ago). (Whyte, 1972, in Khush, 2000). It has been hypothesized that rice was domesticated at several locations within a broad belt, from the plains down the foothills of the Himalaya region in India up to Upper Myanmar. (Chang, 1976; Ramiah, 1937; Roschevitz, 1931, in Khush, 2000).

Different races and types based on genetic and geographic characteristics exist within the species, such as *Japonica*, *Javanica* (belongs to Japonica but separately described because of its importance) and *Indica*. ***Japonica*** belongs to the groups of rice varieties originated from northern and eastern China, grown and extensively cultivated in some parts of the world. *Japonica* type is cultivated in the cooler regions of the subtropics as well as in the temperate zones. *Javanica* races are cultivated in Indonesia and many areas for cultivation in the uplands, which belong to the Japonica race of *O. sativa* having broad, stiff, light green leaves with low-tillering and tall plant stature. *Indica* rice botanically called *Oryza sativa* is cultivated mainly in tropics and subtropics such as African countries, central and southern China, alongside India, Indonesia (Java), Pakistan, Philippines, and Sri Lanka. The three types of rice races are different in many respects, i.e. morphological, phenological, and yield characteristics. *Japonica* has short, roundish spikelets, and the awnless to long-awned grains do not shatter easily, having zero to 20 percent amylose content, while *Javanica* grains are long, broad, and thick, spikelets are awned or awnless with low shattering, having zero to 25 percent amylose content. *Indica* type has long to short, somewhat slender-like and flat grains. The spikelets are without awns, with easily shattering grains, having 23 to 31 percent amylose content.

Rice grains are classified as short, medium and long based on structure, texture and unique properties, including aromatic and cooking features. Long milled grains with a three to four times width, are fluffy and light in composition when cooked. Medium grain rice has a shorter, wider kernel and cooked grains are moister and more tender, and stickier, than long rice, while short grain rice is twice in length of its width having a sticky texture after cooking.

Figure 1. Long grain rice

Figure 2. Medium grain rice

Figure 3. Short grain rice

1.2.2. Nutritional, medicinal and industrial uses of rice

Rice (*Oryza sativa* L.) is of vital importance in human nutrition and is eaten as a staple food by 75 percent of the world population. As a basic staple food for human beings, rice and wheat rank equally in importance. Rice is the principal food for 50 percent of the global population and provides 60 percent of energy in Southeast Asia (Anjum *et al.*, 2007). Rice is a source of energy for 21 percent (per capita) globally and is also a source of protein for 15 percent (per capita) of the global population. Rice has high quality proteins while protein contents are moderate among the cereals besides a rich source of fiber, minerals and vitamins, which is reduced during the milling process except carbohydrates. Myanmar has the highest intake of rice as staple among Asian countries with 211 kg per person per annum (IRRI).

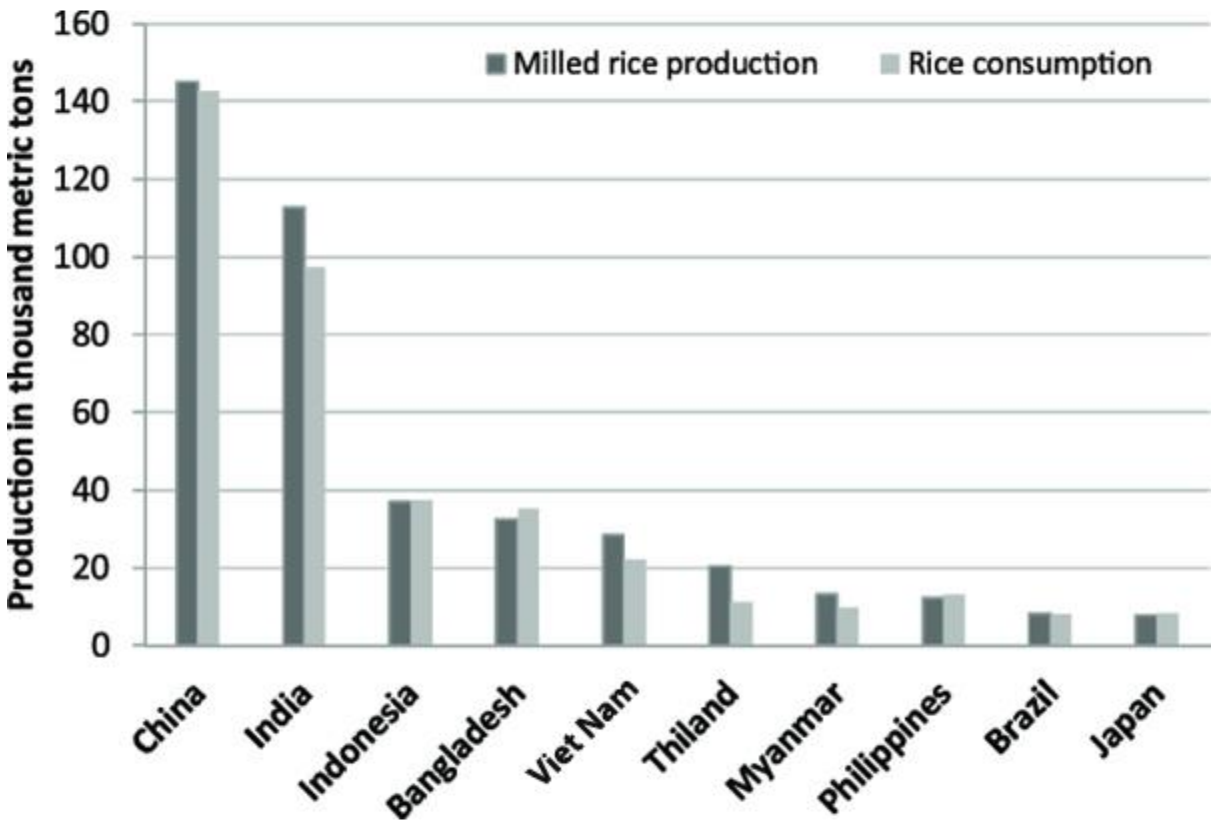
Table 1. Nutritional value of rice based 1/3 cup (66.7 g) of cooked rice

Nutrient proximates	**Brown rice**	**White rice**
Energy	82 calories	68 calories
Protein	1.83 g	1.42 g
Total lipid (fat)	0.65 g	0.15 g
Carbohydrates	17.05 g	14.84 g
Fiber, total dietary	1.1 g	0.2 g
Sugars, total	0.16 g	0.03 g
Calcium	2 milligrams (mg)	5 mg
Iron	0.37 mg	0.63 mg
Sodium	3 mg	1 mg
Fatty acids, total saturated	0.17 g	0.04 g
Fatty acids, total trans	0 g	0 g
Cholesterol	0 mg	0 mg

Source: Healthline. 2017. Brown Rice vs. White Rice: Which Is Better for You? *https://www.healthline.com/health/food-nutrition/brown-rice-vs-white-rice*

Rice industrial byproducts have multifaceted uses in various industries. The milling byproducts such as bran and rice polish are used as livestock feed. Oil extracted from rice bran has significant food and industrial uses. Broken rice is used in the brewing and distilling industry as well as in manufacturing of starch and rice flour. Rice husk is used as fuel, packing materials, industrial grinding and fertilizers manufacturing as well as in preparation of organic manuring and compost making. Rice flour is also used for making noodles, which is extremely popular in many Asian countries including Myanmar. Rice straw after threshing is an important animal fodder source and is also used in livestock bedding, as roofing material, for making mats and various garments, used in garment and packing material sas well as for making broom straw.

Figure 4. Rice production in million metric tonnes



Source: Ali, N. 2019. Aflatoxins in rice: Worldwide occurrence and public health perspectives. ***Toxicology reports*****,** ***6*****, 1188-1197.**
https://www.sciencedirect.com/science/article/pii/S2214750019300253

1.2.3. Economic importance

Rice has a dominant position in the global economy because of its significant importance for human nutrition, and crucial role in human food security. Rice is grown on 155 million ha, accounting for 1/5th of the global calorie supply. However, rice is traditionally cultivated in Asian countries but has been an important staple in parts of Africa and Latin America, with growing importance in the regions. Around 900 million of the world's poor[1] depend on rice as producers or as consumers. Therefore, sufficient and stable supply of affordable rice is crucial for reducing poverty and hunger (Pandey *et al.*, 2010).

Myanmar's economy is clearly dependent on agriculture. Among the agricultural crops, rice plays an essential role not only in food security but also in the nation's economic development. In 2018–2019, rice production was reported 28 megatonnes, and the country's exports was 1.8 megatonnes which was worth about USD 572 million (MoALI, 2019). Rice occupies about 40 percent of the cropped

[1] Poor with daily income below USD 1.25 in terms of purchasing power parity.

area and dominates the agricultural sector; thereby controlling the national economy. Rice is the staple food of the population, and its shortage causes the prices of many other commodities to rise, creating market instabilities. Nearly 70 percent of the population rely directly or indirectly on the rice industry. Rice is thus inextricably interwoven into the economic and social fabric of Myanmar (Win, 1990).

1.2.4. Morphological characteristics

Rice is an annual plant belonging to the grass family and has round, hollow and connected culms. The crop has a life cycle ranging from 105 to 145 days, depending on biotic and abiotic factors. The rice plant has three distinct growth stages during its life cycle. The vegetative phase, starting from germination up to panicle initiation, followed by a reproductive phase from panicle initiation to heading, and final stage from grain filling until ripening i.e. heading to maturity. The three stages correspond to three agronomic and yield parameters, i.e. number of panicles per unit land area, grains produced per panicle and grain weight, determining final grain yield of the crop respectively (Rice Production Handbook).

Rice seed, seedling emergency and seedling growth: Rice grains having dormancy do not germinate until conducive temperature is provided. The part of the seed called coleorhiza enveloping the radicle comes out as germination occurs in an aerated environment such as a well-drained soil. However, if the seeds are germinating in submerged water, then the coleoptile emerges ahead of the coleorhiza with the root, the radical breaks through the coleorhiza shortly followed by the emergence of two-three seminal roots. Within the rice seed, the seed part called coleoptile encapsulates the young leaves. The coleoptile comes out as cylinder shape in different colors, i.e., colorless or pale green, to green or pale purple, to deep purple color. The part between the coleoptile and the point of union of the root and culm is called the mesocotyl, which elongates and uplifts the coleoptile above the ground, giving rise to the seedling, and is then followed by differentiated leaves as the time passes.

Root system: The rice plant has a fibrous root system, possessing subroots and root hairs. The primary roots called seminal roots are not branched and disappear after germination, while the secondary adventitious roots are produced from the underground nodes of the young culm and are profusely branched. With growth of the plant, coarse adventitious roots grow up in the form of whorls from the nodes above the ground.

Culm: The culm, or jointed stem of rice, is made up of a series of nodes and internodes with the node (nodal region) bearing a leaf and a bud. The bud is inserted in the axil between the nodal septum six upper ones. The lower internodes are larger in diameter and thickness than the upper internodes. Tillers emerge from the main culm in alternate pattern. The primary tillers come out of the lowest nodes and produce secondary tillers, which in turn give rise to tertiary tillers.

Leaves: The leaves consist of sheath and blade with the sheath growing along the blade and enclosing the culm in different varying lengths and forms. Leaf blades are generally flat and sessile. The uppermost leaves below the panicle are called flag leaves because of their flag-like appearance and variation in shape, size, and angle from other lower leaves. The upper leaves have parallel veins with midrib as ridge in the middle on the lower surface of the leaf. Auricles are small paired like attachments, borne on either side of the leaf blade. The number of leaves decreases progressively with increase/rise in tillering order.

Rice panicle: The panicle is borne on the uppermost internode of the culm and varies from one to four panicle branches per plant. The panicle (rachis) is the major axis of the rice flower type called inflorescence. The inflorescence stretches from the panicle base to the tip. The panicle develop a racemose mode of branching in which each node on the main axis gives rise to the primary branches and each of which, in turn, bears the secondary branches. The secondary branches bear the pediceled spikelets.

Spikelets: Spikelets arise on the pedicle of the plant and are morphologically peduncules. The apex of the pedicel below the sterile lemmas is expanded into a lobed facet of varying size, shape, and margin, and is considered as spikelet rice, comprising of three flowers, two of which are reduced in development. Thus, the enlarged, cup-like apex is homologous with a pair of true glumes and may be termed “rudimentary glumes”. The rice spikelet comprises of a small axis called rachilla. A single floret arises on the axis of two ranked brackets. The lemma, palea, and the included flower form the floret (Bardenas, 1965).

Figure 5. Rice leaf and culm morphology

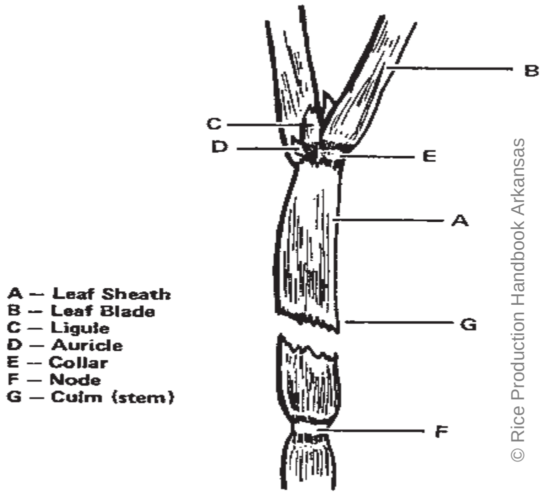


Figure 6. Rice plant morphology

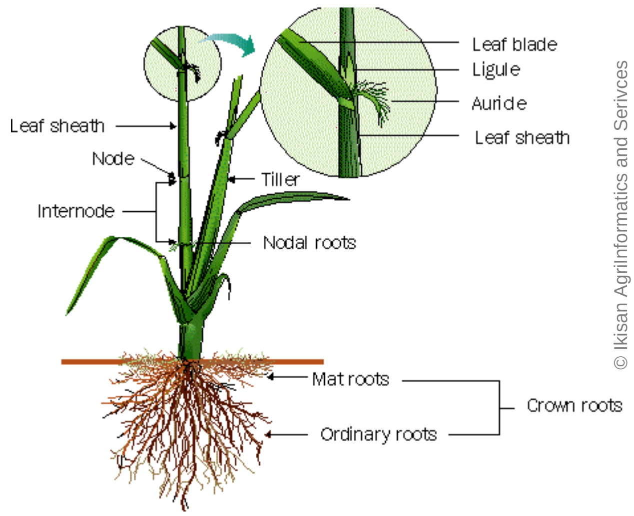


Figure 7. Component parts of rice panicle

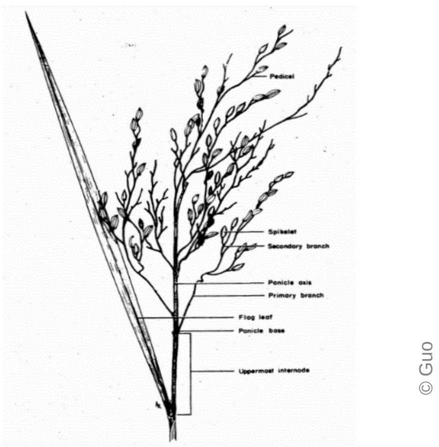


Figure 8. Structure of spikelet

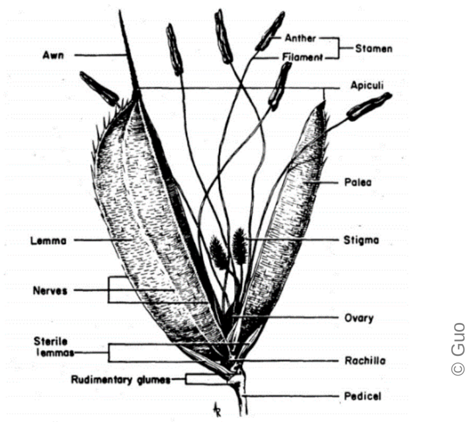


Figure 9. Parts of young, germinated seedlings

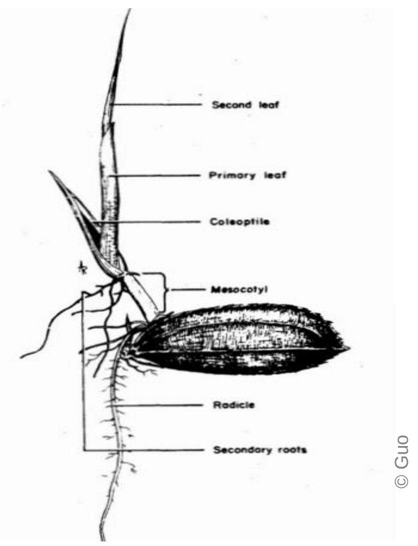


Figure 10. Rice grain/seed structure

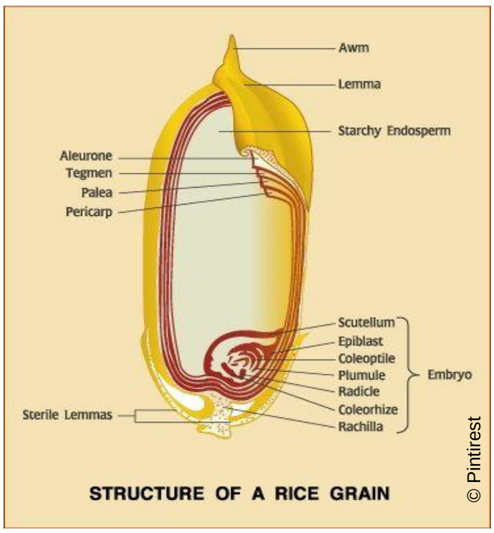
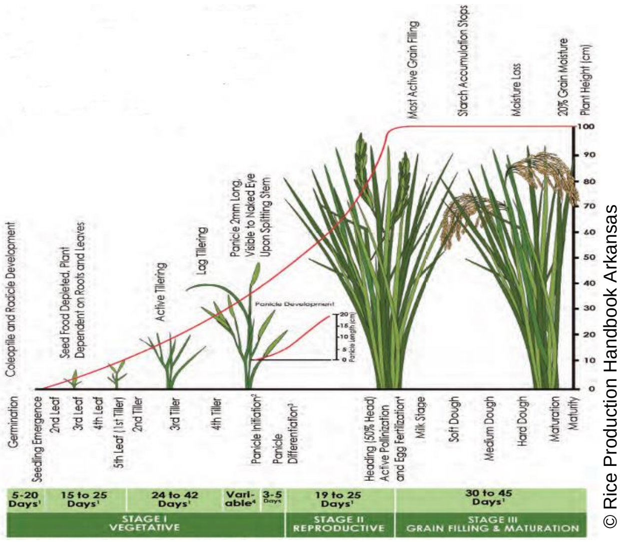


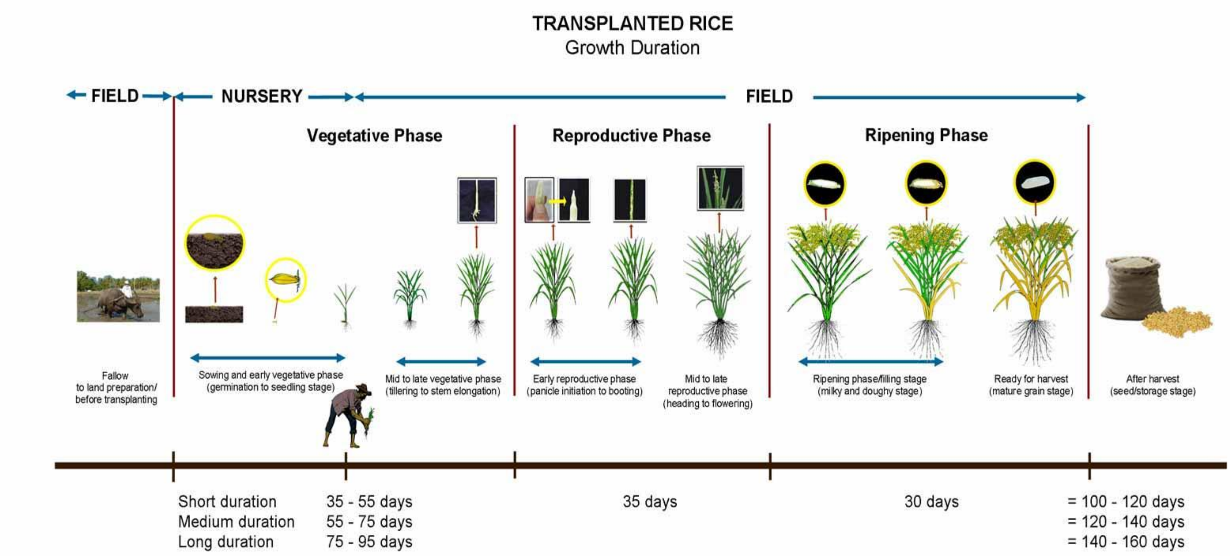
Figure 11. Mature rice grains

Figure 12. Rice plant growth stages



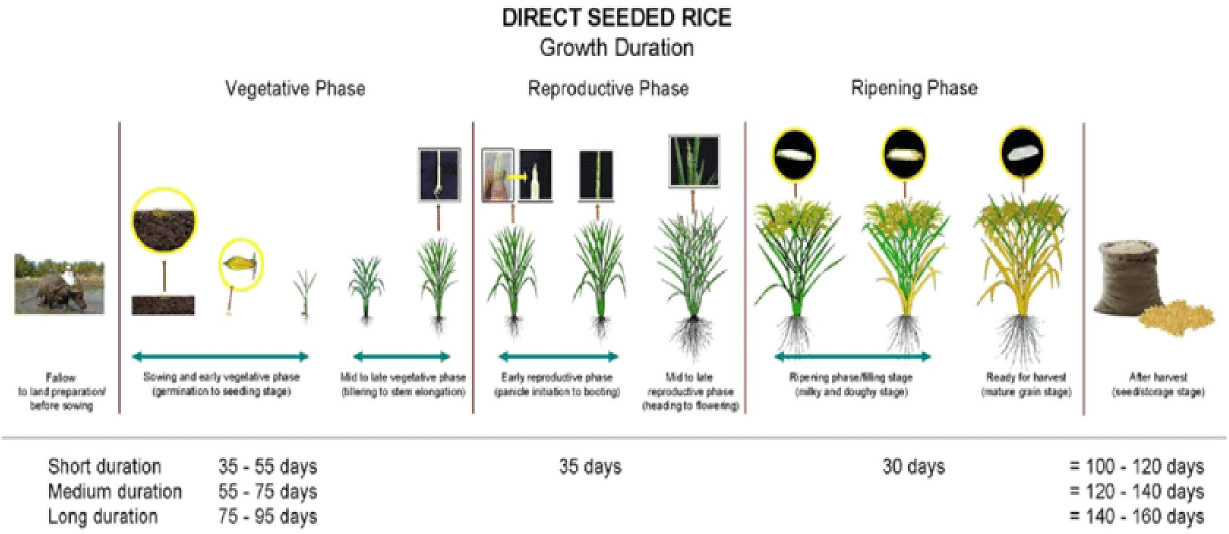
Source: University of Arkansas Division of Agriculture Cooperative Extension Service. 2021. Rice production. https://www.uaex.uada.edu/publications/pdf/mp192/mp192.pdf

Figure 13. Crop growth calendar of transplanted rice



Source: IRRI. 2023. How to develop a crop calendar. http://www.knowledgebank.irri.org/step-by-step-production/pre-planting/crop-calendar

Figure 14. Crop growth calendar of direct seeded rice



Source: IRRI. 2023. How to develop a crop calendar. http://www.knowledgebank.irri.org/step-by-step-production/pre-planting/crop-calendar

1.2.5. Rice production in Myanmar – constraints and opportunities

Rice is the major staple food in Myanmar, which is the world's sixth-largest rice-producing country (CGIAR). The crop was cultivated at an area of 7 149 000 ha, with a total production of 28 016 000 tonnes and yield of 3.92 kg ha^{-1}. Rice production in the country increased manifold over the last two decades in terms of area expansion and yield increase. Myanmar exported rice to the tune of 1 836.46 megatonnes, fetching a foreign exchange of USD 572.42 million (MoALI, 2019).

Table 2. Harvested area, production and yield of paddy and export of rice

Year	Area Harvested (million ha)	Total Production (megatonnes)	Yield (metric tonnes ha^{-1})	Export of rice	
				Volume (megatonnes)	Value (million USD)
2014/15	7 153	28 193	3.94	1 426.88	532.44
2015/16	7 098	28 209	3.97	1 130.22	414.32
2016/17	7 063	27 693	3.92	1 320.80	434.60
2017/18	7 169	28 092	3.92	2 951.81	977.25
2018/19	7 149	28 016	3.92	1 836.46	572.42

Source: MoALI, 2019

The country is endowed with a diverse agroecosystem where rice is cultivated in irrigated, rainfed lowlands, including (late sowing and Mayin area) deep water and upland. Late sown rice in rainfed lowland is sown during monsoon period. Mayin rice is transplanted only after the monsoon when floodwater recedes. Rainfed lowland is the largest ecosystem while deep-water rice is practiced in delta regions and coastal belt of Rakhine state. Delta region covering Ayeyarwady, Bago, and Yangon regions of Lower Myanmar, approximately 60 percent of the rice is cultivated as rainfed rice. Due to varying rainfall and hydrological patterns, irrigation of the crop at the critical growth stages/seasons becomes more important especially in CDZ. In other regions such as delta, due to high risks of floods, drainage of excess water becomes a problem. The country's upland areas of cultivation are mostly in Mandalay, Sagaing, and Shan states. Some upland area in Shan State occupies sloping land, which becomes cold in the northern winter (CGIAR). It is worthwhile to mention that Myanmar has the distinction of producing one of the best rice qualities of Paw San Rice, i.e. Pearl Paw San (World Rice Conference 2011, Viet Nam).

In spite of having comparative advantages as one of the major rice producing countries, the optimum potential of productivity, yield and export is yet to be fully tapped due to the following reasons.

Access to agriculture credit and microfinance facilities: Small farmers are facing issues of access to capital, especially formal sources of credit and microfinance facilities due to which the farmers are unable to buy quality and appropriate quantity of inputs, i.e. fertilizers, resulting into less rice yield. Subsistence rice growers are also compelled to sell out their rice produce at the farm gate after harvesting due to urgent cash needs on one hand and lack of storage and processing facilities on the other (CGIAR, Myanmar).

Less developed agriculture infrastructure: The agriculture infrastructure, especially the irrigation system and farm to market roads, are also reducing the income of small farmers due to high cost of transportation and irrigation management of the crop. The transporters fetch high prices of transportation due to long and poor road and communication infrastructure (CGIAR, Myanmar).

Less adoption of crop rotation: To increase and supplement income from rice, crop rotation is one of the best means to achieve the end of improved soil fertility for increased productivity. The farmers do not practice crop rotation in the rice based cropping system, on one hand due to limited access to supplementary irrigation as well as less knowledge and resources for practicing crop rotation on the other (Naing *et al.,* 2008).

Access to quality seed of improved rice varieties: According to the feedback of rice farmers, own seed collected from the previous crop or collected from neighboring farms is used for rice production instead of securing recommended seed from DoA or other authorized seed dealers. The farmers also reported issues of road infrastructure and long distances due to which they cannot afford to get new quality seed. As a consequence of using old, unimproved seed, a considerable varietal degeneration in the form of low productivity and seed vigor, rice yield has decreased (Naing *et al.,* 2008).

Low and less judicious use of fertilizers and agrochemical: The use of quality agrochemical and chemical fertilizers is of crucial importance in rice production. Due to poor socioeconomic conditions, small farmers are unable to purchase and apply recommended types of fertilizers and agrochemicals. The farmers are less trained in implementation of IPM[2] approaches, which can significantly reduce their cost of production and increase rice yield. Most of the farmers are using nitrogenous fertilizers with less awareness about balanced application of other macro (especially phosphorus and potash) and micronutrients essential for quality and sustainable rice production based on soil test analysis. Application of organic manures (green manures and compost) is also very low in some of the rice growing regions. Fertilizers and organic manures are usually applied to the seedling nurseries but application after transplantation is not appropriately taken care of.

Weeds problem: Though the farmers have the knowledge about major weeds in rice fields, effective weed prevention and control measures are not practiced at different stages of crop management, such as proper seedling cleaning for removal of weed seeds, eradication of weeds seedling at the nursery as well in the field. The right stage of weed control is highly important to ensure weed free cultivation, especially weeds control at the vegetative stage before the production of seeds and rhizomes, which may contaminate the current rice produce and cause weed infestation in the next crop.

Diseases and insect pest: Rice yield and quality can be significantly reduced if appropriate control and prevention of insect pests are not taken. Some farmers use pesticides/insecticides but are not properly aware of quality, method and time of recommended agrochemicals. A wide array of insect

[2] IPM is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines.

pests such as stem borer, leaf folder, brown plant hopper, gall midge and diseases like bacterial blight, bacterial leaf streak, root rot, and false smut, negatively affect rice growth and productivity. However, the farmers have reported high infestation of stem borer, leaf folder; case worm and armyworm as the major insect pests. The common diseases include bacterial leaf blight and rice blast (please refer to rice IPM handbook of the project).

Processing and storage facilities: Small farmers are lacking improved storage and processing facilities due to which they are selling out their produce to the middlemen at cheap prices after harvest. The profit margin earned by the intermediary is high, but does not trickle down to the producers. Due to low quality and less improved processing facilities, Myanmar is getting only 30 percent of the export price of rice received as compared to other ASEAN countries.

Figure 15. 2023 states/regions wise rice production in Myanmar

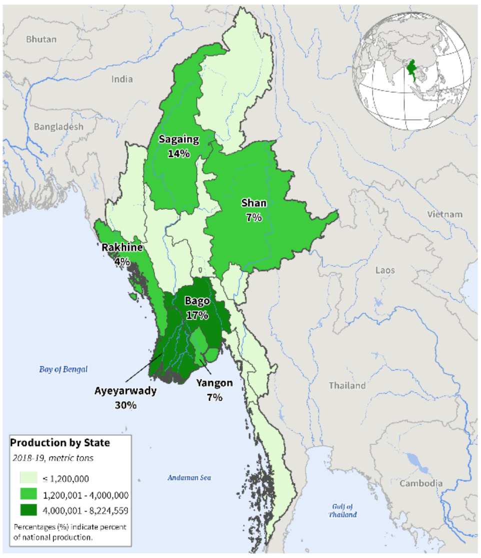
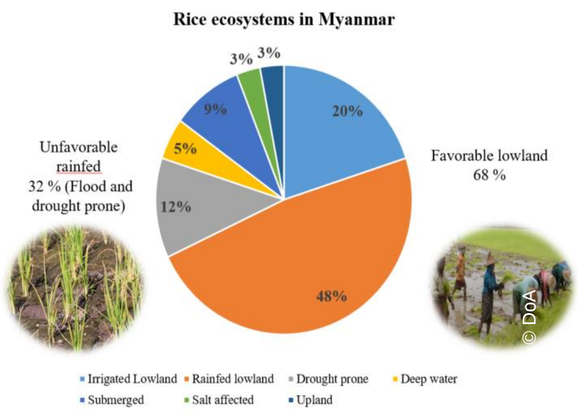


Figure 16. Rice ecosystem in Myanmar



Source: USDA. 2023. Burma: Rice Production. https://ipad.fas.usda.gov/rssiws/al/crop_production_maps/seasia/Burma_rice.png [Cited 31 October 2023]

CHAPTER 2 – PADDY PRODUCTION STATUS IN MYANMAR

2.1. Production requirements and systems

Rice can be successfully grown in a wide range of climatic and soil conditions. Different rice types/strains and varieties respond differently to climatic conditions. However, certain environmental conditions are essential for optimum growth and productivity.

2.2. Climatic requirements

2.2.1. Temperature

Rice is a tropical and subtropical plant. As such, temperature is another climatic factor that significantly influences the development, growth and yield of rice. Rice requires a high temperature between 20 and 40°C. The optimum temperature of 30 °C during daytime and 20 °C during nighttime seems to be more favorable for the development and growth of rice crop (Mitin, 2009). In temperature higher than 40 ℃, seedlings cease growth and may die. A temperature lower than 10 ℃ is not suitable for seedling growth. If the temperature exceeds that of the crop tolerance limit, it can cause increased sterility at the flowering stage. High nighttime temperature at grain-filling causes a decrease of photosynthetic activities of the plant and impairs grain-filling efficiency of the crop (Rice production handbook Arkansas).

2.2.2. Moisture/Rainfall

Rice water requirements are high as compared to other crops. Assessing the exact water requirements from irrigation and rainfall is difficult from transplanting to harvest as it can be determined by many factors such as soil types, growing periods, climatic conditions, including rainfall and relative humidity, method and type of irrigation, irrigation efficiency and rice varieties. However, the crop normally requires 800 to 1 200 mm of water with extremes between 520 and 2 550 mm during the growing season. The crop daily water requirements range from six to 10 mm. Sandy soils with low water retention capacity and percolation losses can increase the water demand. Daily water consumption requirement of rice for various types of soils are 26.9 mm for sandy soils, 22.5 mm for sandy loam soils, 17.3 mm for loamy soils, 14.7 mm for clay loam soils and 13.0 mm for clay soils (Small Scale Irrigation System, 1983).

2.2.3. Photoperiod

Rice is sensitive to photoperiod and its yield is influenced by solar radiation, especially during 35 to 45 days before maturity. Bright sunshine with low temperature during the ripening period of the crop helps in the development of carbohydrates in the grains, resulting in improved seed density and quality (Mitin, 2009).

2.2.4. Soil requirements

Rice can be successfully grown in loam, silt loam, sandy loam, and silty clay loam soils. The optimum soil pH for rice growing is 5.5–7.0 (Myanmar GAP guidelines, 2018). Fertile riverine alluvial soils and clay loam soils in monsoon lands have the high moisture retention capacity and are the best for rice cultivation. 135-140=>135–140

2.3. Production systems by agroecosystems

Global food security and abiotic stresses (climate change, drought, rising temperature and salinity) have prompted rising food demand. These and many other socioeconomic factors resulted in declining yield of rice, soil fertility and productivity, especially within the intensive rice based cropping systems; moreover, degrading natural resources, especially soil and water, have given rise to various techniques of rice production systems. The labour-intensive nature of the crop and shortage of labour has further intensified the need to introduce more labour and input efficient systems of rice cultivation. With the conventional wet tillage operations for producing rice through puddled rice transplanting, the situation is further exacerbated by damaged soil structure, decreased land, and water and farm operations efficiency. To minimize the negative impacts of soil and resource degrading systems, new productions systems have been developed such as zero tillage, direct rice seeding, water seeding, strip planting and SRI, complemented by innovations in machinery. It has been scientifically determined that non-puddling rice cultivation with increased crop residues retention, improved soil organic carbon by 79 percent and total nitrogen in soil by 62 percent as compared to conventional rice cultivation through puddling (Alam *et al.*, 2020).

Based on the different agroecological zones of Myanmar, rice is cultivated under different systems according to the climatic conditions, seasonality aspects, soil type and fertility status, rice varieties performance and water management perspectives, which give a comparative advantage to the country in terms of diversity of rice cropping systems. As mentioned earlier, rice crop has a wider adaptability to climate such as temperature, subtropical and tropical climatic conditions with varying weather from arid and semiarid to subhumid and humid climates. Due to the unique nature of the crop among the cereal, rice production ecosystems, encompass irrigated lowland, irrigated upland, rain-fed upland and deep-water ecosystems (Rao *et al.*, 2017).

2.4. System of rice intensification (SRI)

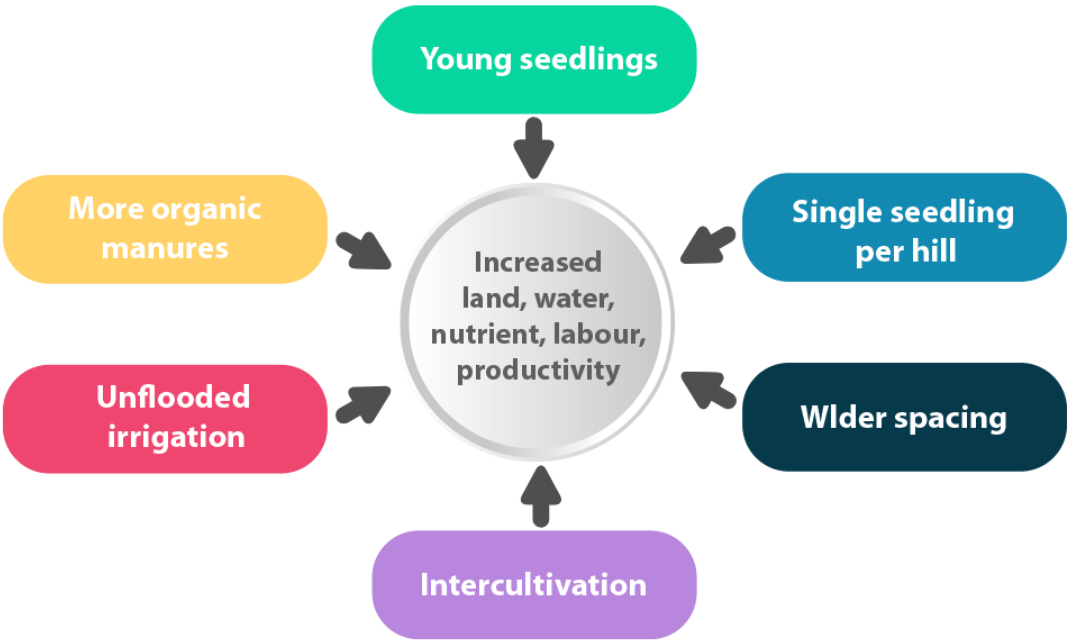
The SRI is a method of rice cultivation for increasing rice production using reduced planting density, use of much organic manures, using non-flooded/aerobic field conditions and young seedlings planted at wider spacing in a square pattern, managing the crop with intermittent irrigation that keeps the soil moist but not inundated, and using weeders for weed control and improving aeration. The practice is based on precise techniques of meeting optimum rice nutrientla and water requirements (Thiyagarajan and Gujja, 2012).

Table 3. Principles and practices of SRI

S.No	Management parameters	Principles	Recommended practice
1	**Crop establishment**	Use young seedlings to preserve plant inherent growth potential for rooting and tillering	8–15 day old seedlings with 3 leaves grown on raised beds
2	**Transplanting**	Transplant single seedling per hill in a quick and careful manner to prevent /minimize damage to seedling roots	Plant seedling as soon as possible and plant carefully at a depth of 1–2 cm.
3	**Plant population and planting geometry**	Reduce the plant population radically by spacing hills widely and squarely, for better growth and root development and access to nutrient and exposure to sunlight.	Planting at grids of 20 x 20 cm or 25x25 cm (or 30x30 cm or even wider if the soil is very fertile) using a rope or roller marker to achieve precise inter-plant distances (to facilitate inter-cultivation)
4	**Crop water management**	Provide water up-to the plant requirement but do not apply water in excess over plant requirements	• **Up to panicle initiation:** Irrigate to 2.5 cm depth after the water ponded earlier disappears and hairline cracks are formed on the soil surface (alternate wet and dry method). • Heavy clay soils should not be permitted to reach the cracking

			• **After panicle initiation:** Irrigate to a depth of 2.5 cm one day after the water ponded earlier disappears.
5	**Inter-cultivation for improved aeration**	Practice precise mechanical inter-cultivation for enhancing aeration for better root growth and beneficial aerobic soil organisms.	• Operate mechanical weeder for inter-cultivation at 10–12 days interval, starting 10–12 days after transplanting and continuing until the canopy closes • Pass between the rows with weeder, and make perpendicular passes across in the field
6	**Soil management**	Maintain organic matter in the soil by applying organic manures for improving soil structure/ texture and soil microorganism for high rice yield.	Apply farmyard and green manures, bio-fertilizers and compost for increased organic matter on soil test basis.

Figure 17. The six principles form the 'SRI Hexagon,' and when adopted together they have a profound effect on the growth of rice plants



Source: Elaborated by the author

Crop Management Calendar under SRI											
	Field preparation and nursery raising		Planting	Tillering					Panical Initiation	Flowering	Maturity
	Days beore planting			Days after planting							
	15 to 20	1 to 5		7	10 to 12	20 to 22	30 to 32	40-42			
Main field	Plowing Puddling	Leveling	Provide drainage at the periphery								
Nursery	Prepare raised bed, sow treated and pregerminated seeds	Spray 0.5 % urea if seedling growth is poor 5 days before planting	Pull out 3 leaf stage seedlings along with soil half hour before planting, root dip with biofertilizers								
Manures	Apply FYM/GM or incorporate	Apply biofertilizers									
Marker use		Use marker on the previous day before planting									
Planting			Plant single seedling at the intersections of marker grid lines or use rope	Fill gaps if needed							
Irrigation	Irrigate to puddle and level	Drain water two days before planting	Irrigate lightly to keep a thin film of water fore planting	Irrigate to 2 cm depth after thin cracks develop on soil surface, drain excess rain water						Irrigate 2 cm water after disappearance of surface water, drain excess rain water	Drain water
Fertilizers		Apply recommended basal dose of N, P , K, Zn				Top dress N and K			Top dress N and K	Top dress N and K	
Inter-cultivation					First	Second	Third	Fourth			
Hand weeding					Remove weeds left out by weeder						
Pest control	Need-based biopesticides / pesticides										

Step by step rice crop establishment under SRI

Figure 18. Seed treatment and soaking

Figure 19. Seedbed preparation for SRI method in Yesagyo township, Magway region

Figure 20. Nursery raised with SRI method in Yesagyo township, Magway region

Figure 21. Land preparation for transplanting in Yesagyo township, Magway region

Figure 22. Seedlings transplanted at younger age (2–3 leaf stage)

Figure 23. Plant only single seedling per hill instead of handful

Figure 24. Geometrical layout using calibrated manual liners

Figure 25. Transplanting seedling in Yesagyo township, Magway region

Figure 26. Using mechanical weeder across the rows in Yesagyo township, Magway region

Figure 27. Rice field of SRI method at maturity in Yesagyo township, Magway region

Figure 28. Alternate wetting and drying avoiding extreme drying and inundation

Figure 29. Robust tillering of rice plant raised with SRI

Figure 30. Tillering and prolific root development of rice established under SRI

Figure 31. Harvesting of rice in Yesagyo township, Magway region

2.5. Crop establishment

2.5.1. Site selection

It is important to carefully select a site for safe and quality rice production. Sites should be assessed for prevention or minimization of chemical and biological hazards and must not have been used previously for disposal of hospital or industrial waste, and livestock farms (Myanmar GAP Guidelines, 2018). Low-lying soils with risk of inundation and defective drainage, sites with shading effects should be avoided for rice nursery raising and transplantation or cultivation. The sites should be well exposed to sunlight. In case of new sites, the risk of contamination as on-and-off sites should be assessed and, if necessary, relevant remedial actions should be taken to prevent or minimize the potential hazards. A site map should be prepared showing the following aspects:

- crop production site with environmentally sensitive areas and highly degraded areas;
- areas for chemical storage, mixing, chemical treatment and spaces used for cleaning of equipment and remedial measures for prevention or minimization of risks;
- areas or facilities used for storage, mixing for composting, fertilizers and soil additives should be represented and remedial actions taken and documented;
- water courses, sewage and drainage lines, areas of active run off and discharge points;
- farm buildings, farm structures and roads; and
- areas of active degradation and planned actions for minimization of current and potential degradation.

The sites of production and post-harvest management should comply with Myanmar Legislation and National Plans related to protection and the prevention of air, water, noise, soil, biodiversity and other environmental issues.

If any risk of hazardous substance contamination exists, the soil should be collected at random and analyzed at least once before rice cultivation by an official or officially accredited laboratory. The results must be kept as evidence.

Site selection: Refer to Myanmar GAP Guidelines in Annex 1, for practices at S.No. 1.1 and ASEAN GAP Guidelines in Annex 2.2 for practices at S.No 2.2.1, Annex 2.3 for practices at S.No. 2.3.1	***Record keeping:*** The record of the field production sites should be kept as per the details given in Annex 3 (Form-1. Site Inspection; 1 to 5 and Surrounding Areas; 1 to 3).

2.5.2. Land preparation

Rice is grown in loam, silt loam, sandy loam and silty clay loam. It can be cultivated in both irrigated and rain-fed areas where water is available. The optimum soil pH for rice growing ranges from 5.5 to 7.0 (Myanmar GAP Guidelines, 2018).

Land preparation is an important cultural operation in rice production in terms of weed control, effective nutrient management, rice plant root development, water and fertilizers use efficiency. Land can be prepared in different ways ranging from zero or minimum, to a much 'puddled' soil which actually destroys soil structure in line with rice production systems under dry and wet soil methods of production. The following considerations should be kept in mind while preparing land for rice cultivation:

- Break the clods for better plant establishment after transplanting.
- Remove weeds before, during and after land preparation to ensure weed-free rice crop and thus reduce labour for weed control.
- Add crop residues (compost, FYM and green manuring) for improving soil texture and water holding capacity.
- In case of problem soils, incorporate recommended soil amendments or fertilizers which take longer in dissolution and uptake by the plants, especially phosphate and potash fertilizers.
- Insect pests and disease should be controlled through destruction of eggs, larvae and breeding places through exposure to the sun by desiccation.
- Ensure to leave the soil surface rough for the control of wind and water erosion.

Control of invisible pests

Golden apple snails eat young and emerging rice plants. They cut the rice stem at the base, destroying the whole plant. Hence, snail management is critical during the first 10 days of transplanted crops, and the first 21 days of directly wet-seeded crops; more specifically, during land preparation and crop establishment or planting. (Rice production Manual-IRRI)

Figure 32. Golden apple snails sticking to the base of the rice plant

Figure 33. A cluster of eggs mass on rice leaves

Primary tillage: To prepare the land, primary tillage should be done after the harvest of the previous crop or at the end of the fallow period. The land should be tilled at appropriate moisture conditions for easy and uniform tillage. Primary tillage can be done through animal or tractor drawn implements, such as disc plow, moldboard plows, tined or rotavators up to a depth of 100 to 150 mm.

Secondary tillage: Secondary tillage is undertaken after primary tillage by tilling the soil three to four times up to 50 to 75 mm depth, depending on the nature of the soil and other conditions such as cloddiness, level of weed infestation, the need, type and method of fertilizer application, as well as the need for puddling. Implements used for secondary tillage include disc and peg tooth harrows, tined cultivators and rotavators.

Figure 34. Primary tillage operation using a tractor drawn plow

Figure 35. Secondary tillage operation using a disc plow

Puddling: In order minimize water losses through water percolation and prepare the soil surface for crop establishment, puddling is done in a very flooded state. Puddling operations are normally carried out through tractors and rotavators or animal-drawn peg tooth harrows. In case of small landholding, puddling can also be done manually, using appropriate tools.

Figure 36. Puddling using caged wheels

Figure 37. Using rotavator for puddling in Yesagyo township

Figure 38. Using water bullocks for rice field puddling in Yesagyo township, Magway region

2.5.3. Recommended varieties, seed and seed quality

2.5.3.1. Seed selection

According to the findings of the GAP-project situation analysis, 63 percent of interviewed farmers ranked access to quality seed of improved varieties as one of their main concerns:

- Good quality and seeds of locally adaptable varieties, free from pest and disease, should be selected and used for rice production.
- Seeds of known origin, yield characteristics, free from physical damages and diseases, are important considerations for improved rice production.
- The seeds must have more than 80 percent of germination, 98 percent of seed purity and less than 0.5 percent of other varieties.
- Seed source should be from official (licensed) places such as Central Seed Farms, Rice Research Centres or Seed or Cooperative Farms, and other recommended sources offered by responsible organizations.
- Alternatively, the farmers can produce their own seeds in their own field separated from grain production areas or other selected fields where the characteristics of plant variety are uniform;
- Seeds produced in the field where rouging is done properly should be used.
- Seed source record and type cultivated should be maintained properly (Myanmar GAP Guidelines, 2018).

Germination Testing –an easy way

In order to test rice seed germination to prevent seed use with low germination, the following simple steps should be followed:

- Select a subset of seeds from the small random samples to be planted (e.g. 200 seeds). Soak the seed in water for 24 hours.
- Arrange 100 soaked seeds in a grid pattern on a wet paper towel.
- Place the paper in a closed container or cover the seeds with another moist paper towel and roll together, placing the sample in a plastic bag.
- Ensure paper remains moist (but not wet to the point of water running off, or seed will rot).
- Count the germinated seeds three and five days later and record how many have germinated.
- Compute the germination percentage using the following formula.

$$\textbf{Germination percent} = \frac{\textbf{No. of seeds germinated}}{\textbf{Total No. of seeds in the tray}} \times 100$$

At least 80 seeds should have germinated to be considered "good seed" (80 percent germination).

Varietal purity tests include looking for percentage of (1) germination, (2) other mixed in varieties, (3) weed seeds and other crop seeds, (4) inert material (stones, soil, etc.), (5) red rice seeds, and (6) moisture content.

Figure 39. Good quality seeds are uniform in size, full, and plump

Figure 40. Poor quality seeds are often discolored

High quality seeds are free from weed seeds, seed-borne diseases, insects, pathogens, and other extraneous matter. They should also be free from various types of mechanical injury that reduce germination and seedling vigor.

2.5.3.2. Recommended varieties

To improve productivity, yield stability, high market return and insect pest resistance, as well as nutritional value of rice, the following DoA-recommended varieties and considerations should be used for rice cultivation:

- The seed should have good grain quality, especially excellent cooking characteristics, attractive color, shape, taste and aroma, as well as head rice recovery.[3]
- The varieties should have market demand both in the local and international market.
- The varieties should have high yield potential and stability over seasons, i.e. give uniform yield over the cultivation seasons and under different rice production systems.
- The varieties should have maximum tillering capacity for better weed competition and productivity;
- The varieties should have tolerance to major diseases, insects, and other stresses (i.e. drought and flood) in the local area(s).
- The varieties should fit in the growing cycle in terms of maturity, matching different seasons and photoperiods.
- Varieties having different planting and harvesting characteristics than other rice varieties in the areas should be avoided to minimize pest damage (e.g. birds during maturation), and growth problems during times of harmful environmental conditions (e.g. late-maturing varieties running out of water).
- The varieties should be lodging-resistant for better crop management, especially reduced losses through shattering at harvest, besides high productivity potentials.

Table 4. Recommended paddy varieties in Myanmar

Variety Name	Growth Cycle (day)	Yield Potential (kg ha^{-1})	Plant height (inch)	Prominent traits
Aye Yar Min	140–145	3 608–4 639	53	Suitable for irrigated and rain-fed areas, soft and smooth eating quality
Ma Naw Thu Kha	135–140	5 155–6 186	41	Suitable for irrigated and rain-fed areas

[3] Head rice' is defined as any grains that are whole to less than 3/4 broken after milling. Head rice recovery is expressed as a percentage of the total milled rice that may vary from as low as 25 percent to as high as 65 percent (IRRI Rice Knowledge Bank).

SinThu Kha	138–140	4 639–6 701	42	Resistance to bacterial blight
Shwe Ma Naw	115–117	4 124–5 155	30	Resistance to bacterial blight, suitable for irrigated areas,
Manaw Hayi	140–145	3 093–4 124	55	Resistance to bacterial blight, suitable for irrigated/rain-fed areas
Shwe Pyi Htay	125	4 639–5 155	39	Aromatic, Resistance to bacterial blight, suitable for monsoon rice in irrigated/rain-fed areas
Palae Thwe	135–140	4 124–5 155	47	Resistance to bacterial blight and blast, suitable for irrigated areas
Yadanar Toe	120–125	5 155–7 217	49	Resistance to lodging, suitable for irrigated/rain-fed areas
Mhaw Bi- 2	135–240	4 124–5 155	48	-
Sin Aye Gayi - 3	125 –130	4 124–5 155	48	-
Shwe Thwe Yin	105 –115	4 124–5 155	36	-
Yet- 90	95	5 155–6 186	30	Suitable for irrigated/rain-fed areas,
Yeanelo - 3	120	2 577–6 186	44	Suitable for the irrigated areas where water-saving irrigation is practiced
Yeanelo - 4	117	4 639–5 155	47	Drought tolerance, blast resistance,
Yeanelo - 5	116	4 639–5 155	50	Drought tolerance, resistance to bacterial blight
Yeanelo - 6	110	4 639–7 217	47	Drought tolerance, blast resistance
Yeanelo - 7	116	3 093–6 186	47	Drought tolerance, resistance to bacterial blight

Source: DAR, 2018 and DOA- Extension Division, 2006$_a$ and 2006$_b$

Seed Selection	***Record keeping***
See Annex 1 of Myanmar GAP Guidelines for practices at S.No. 1.3 and Annex 2.1 of ASEAN GAP Guidelines for practices at S.No. 2.1.2, annex 2.2 for practices at S.No. 2.2.2, annex 2.3 practice 2.3.2	Details of planting /propagation materials (seeds) such as variety, source of supply, amount of supply and the date of supply for seeds, seedlings and plant propagations should be recorded as per Annex 3 (Form-1. Seed selection; 1 to 3, Form-2. Seed/Seedling; 1).

2.5.3.3. Seed treatment (soaking)

In order to break the dormancy for increased germination and better seedling growth, seeds should be treated using the following treatments:

- ***Exposure to high temperature:*** The seeds are to be exposed to high temperature (40–42°C) for one to two days before sowing.
- ***Seed priming:*** Seed soaking is beneficial for maximum germination. The seeds should be soaked for four to eight hours in clean water and re-dried through spreading on a clean mat/tarpaulin. The seed should be sown one to two days after priming.
- ***Pre-germination:*** The seed should be dipped in water for 12 to 24 hours until small shoots appear at the end of the seed. The duration of soaking can increase in case of cold weather, i.e. 36 to 48 hours. After soaking, water should be carefully drained to avoid damage to the pre-germinated seeds. Dried seeds should be placed in a bag for 24 hours, in a shady area, with good air circulation. The temperature during drying should not increase than 42^{0}C, as increased temperature may damage the seeds. The roots should not exceed five mm at the time of sowing, either through broadcast or drum seeding.

2.5.3.4. Seed rate and method of sowing

Levelling of rice fields could reduce the seed rate if there are no rats, birds or weed problems. Once uprooted, transplanting should be done to reduce the shock to the young seedlings. Seedling age at transplant is important for the desired crop stand and plays an important role in tillering capacity of the plants per hill. (Ginigaddara and Ranamukhaarachchi, 2011, p. 76). The age of the seedlings at the time of transplanting should be 20 to 25 days using two to three plants per hill at 1.5 inches of seedling depth. Skip one row/six rows for seed production and one row/10 rows for grain production. The age of seedling at transplanting and number of plants per hill are important to get the proper plant population density. (Myanmar GAP Guidelines, 2018). It is suggested that WSR seed rates can be used to adjust the expected stand losses when seed is broadcasted or drilled on a puddled field, considering seed germination percentage. Recommended seed rates based on different sowing methods are given in the table below:

Table 5. Planting geometry and sowing method

Season	Planting geometry		Seed rate (kg ha^{-1})	Plant population ha^{-1}	Seeding/seedling depth (inches)
	Row to Row (inches)	Plant to Plant (inches)			
Transplanting	8	6	32–52	322 000	1.5
	8	8	52	242 000	1.5
	9	6	52	287 000	1.5
Wet seeding	-	-	77	-	-
Dry seeding	-	-	103	-	-
SRI	10	10	4	155 000	1.0

Source: MOALI. 2018. Myanmar GAP Guideline. Department of Agriculture. Ministry of Agriculture, Livestock and Irrigation: Nay Pyi Taw, Myanmar, 2018. https://www.moali.gov.mm/en
DOA-Rice Division. 2016. Pamphlet of Rice Production Technologies for Monsoon and Pre-monsoon Seasons. Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.

2.6. Rice nursery raising for transplanting

2.6.1. Wet bed method

When sufficient water is available, the wet method is used for nursery raising by allotting a specific portion of the field, normally a corner, for the nursery. A seed rate of 30 to 50 kg for transplanting to one ha of land is sown in the properly puddled and leveled bed. One meter wide and with a convenient length, soil is raised five to 10 cm above the field level. Pre-germinated seeds are broadcasted in the plot with the proper drainage system for removal of surplus water. Organic matter (compost or FYM) and other inorganic fertilizers are applied as basal dressing for increased seed vigor and easy uprooting of seedlings. Depending on the soil and local climate, normally 15 to 21 days old seedlings are transplanted to the main field.

Figure 41. Seed bed preparation for rice nursery raising using wet bed method

Figure 42. Nursery raised using wet bed method

2.6.2. Dry bed method

The nursery is prepared in dry conditions at a site fully exposed to sunlight and with uninterrupted access to irrigation water. One tenth of the field site is spared for nursery cultivation. The bed is prepared through removal of weeds and breaking clods by making it more friable. Depending on soil fertility, organic and inorganic manures are applied in recommended quantities and appropriately mixed with the soil. Care should be taken that the bed level is 5 to 10 cm high with one meter width and convenient length. Well-decomposed crop residues, free of weed seeds are spread over on the nursery bed to facilitate easy uprooting. Ensure timely irrigation to avoid damage to the roots and keep the bed partially wet at the time of uprooting. A nursery of 15 to 21 days old is transplanted into the field. As evidenced, seedlings raised through the dry bed method are short but strong and have a proliferated root system as compared to seedlings raised through a wet bed.

Figure 43. Dry bed prepared for rice nursery raising

Figure 44. Germinated seedlings raised on dry bed

2.6.3. Dapog method

The Dapog or mat method of nursery raising is especially appropriate for growing short duration varieties and thus less exposed to shocks due to transplanting. The method is less labour-intensive and has minimal root damage as compared to the wet and dry bed method. The nursery can be raised through the mat method where the surface is flat and has sustained water availability. A 100-meter square field is prepared. A seed rate of 40 to 50 kg is sown for an area of one ha. In order to ensure proper geometrical layout of the plot, a one-meter wide and 10 to 20-meter-wide plot is marked. Inserted sheets such as banana leaves or plastic sheets should cover the surface by making proper boundaries, with the aid of bamboos shoots or banana sheath. The seedbed is covered by partially decomposed rice husk or compost. The seed is cultivated at one kg 1.5 m^{-2}. Water is sprinkled after sowing, followed by pressing down by flat wooden plank to embed the seeds and make the surface smooth. The bed should be kept moist to prevent water stress. The seedlings are transplanted after nine to 14 days to the main field.

2.7. Transplanting

Transplanting rice seedlings at the right time, stage and method significantly influences the crop stand at the main field. Seedlings should be transplanted before 25 days after sowing as transplanting of old seedlings may result in low yield. In case the seedlings are long, then the tip of the seedlings can be cut for easy handling and transplanting.

Line sowing is more advantageous as it requires less seed, produces a more even crop, facilitates effective weeding and disease management, contributes to increased water and fertilizer use efficiency and other farm operations, besides high yield and quality rice

Record keeping

Sowing method, seed rate and field layout map should be recorded as per Annex 3 (Form- 1. Cultivation Method; 1 to 3).

2.7.1. Rouging and weed control

Rouging and weed control measures at appropriate times should be practiced during the crop growing season. Therefore, regular monitoring of off-type inspection and rouging should be done at tillering, flowering and ripening stages, respectively:

- At tillering stage, any off-types that are different from the characteristics of the target variety in terms of tiller type, leaf stature, leaf colour, stem colour, leaf size and plant height are checked and removed immediately during the tillering stage.
- At flowering time, any off-types that are different from the characteristics of the target variety in terms of early/late flowering time, spikelet shape, colour of spikelet and male pollen are checked and removed immediately during the flowering time.
- Any off-types that are different from the characteristics of the target variety in terms of type of spikelet are checked and removed immediately during the reproductive stage.
- Any off-types that are different from the characteristics of the target variety in terms of seed size, seed colour and type of ripening during the ripening stage (Myanmar GAP Guideline, 2018).

2.8. Manures and fertilizers

2.8.1. Integrated nutrient management (INM) in rice

Balanced use of fertilizers is a basic requirement for maximum return. Keeping in view diverse rice production systems, the nutrient requirements of the crop varies, depending on soil fertility, soil physiochemical properties, climatic conditions, water availability and system of rice cultivation. In case of lowland rice, environmental conditions are stable and appropriate, therefore application of nutrients increase yield. However, in case of upland rice due to inadequate water particularly at flowering, yield is drastically reduced even if sufficient fertilizers are applied. It is important to apply fertilizers in line with crop water availability, and nutrients application should be managed for increased nutrient use efficiency and yield (Tahir et al, 2019). Important issues in rice growing areas are soil fertility issues, shrinking water resources, increasing soil salinity, erosion of soils -especially in areas along the rivers/deltas and coastal areas,- high cost of inputs, especially chemical fertilizers, and access to affordable financial options. There is a need to promote integrated plant nutrient management systems in study areas of CDZ (Shrestha *et al.*, 2019). In view of climate change, judicious use and integrated management of soil fertility is highly important for climate smart, sustainable and regenerative farming for food and environmental safety and to reduce soil degradation. 4R (Right Source, Right Time, Right Dose/Quantity and Right Placement) nutrient stewardship is based on certain principles considering the social, economic and environmental dimensions of a production system (Fageria *et al.*, 2011).

Figure 45. Integrated plant nutrient management model

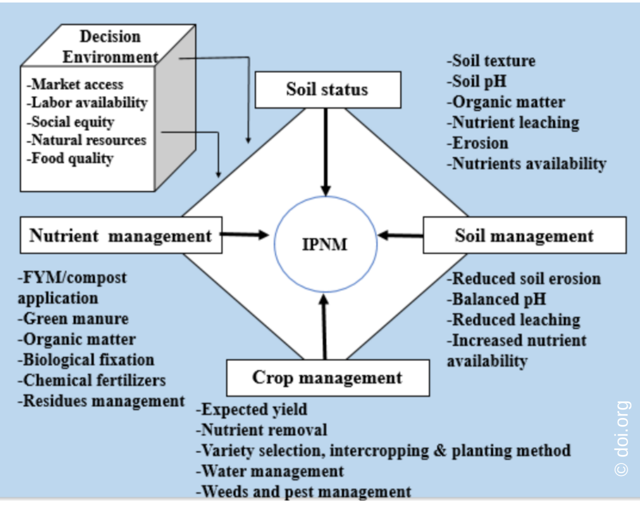
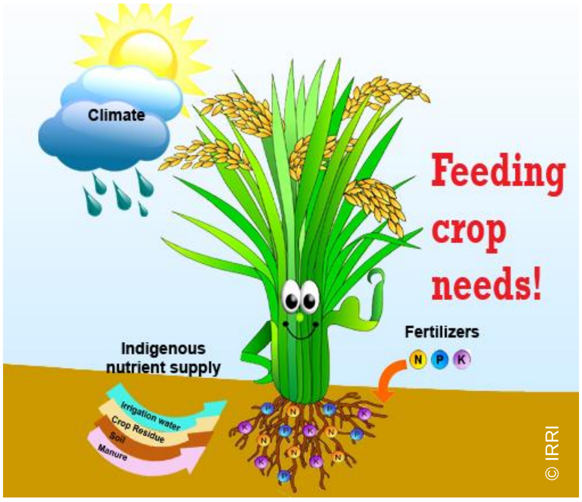


Figure 46. Site specific and integrated nutrient management approach in rice



It is highly important that fertilizers and soil additives used are free from chemical and biological contaminations that may be harmful on and off-site. The natural fertilizers should be used after complete decomposition and when fully converted to compost. Areas or facilities for mixing and loading of fertilizers and soil additives, storage and for composting of organic matter must kept away from the produce or production sites to avoid contamination. The registered products are only purchased from licensed suppliers and used for crop production. The application of fertilizers and soil additives is recorded. A record is kept of soil amendment practices taken for improving its properties. Application of pesticides or seed treatment for prevention of soil insects are avoided to minimize the harmfulness to the effective microbes. Summer ploughing is recommended for soil quality improvement. It is recommended that fertilizer application should be done based on plant growth in fertile soils (alluvial soils). The following practices are recommended for crop production with GAP:

- Amount of fertilizer should be calculated and applied based on the plot size and indigenous nutrient contents.
- Before fertilizer application, weed control should be done, especially in the early vegetative stage, and irrigation water should be checked and maintained about two inches deep in the field. Regular irrigation should be ensured (three to five days) after fertilizer application.
- The right amount of fertilizer at the right time is applied depending on different rice varieties and different soil types (Myanmar GAP Guidelines, 2018).

2.8.1.1. Chemical fertilizers

2.8.1.1.1. Macronutrients (4 R nutrient stewardship for rice)

Nitrogen

Nitrogen management in rice has a challenging aspect in terms of applying the right rate and type of fertilizer to achieve maximum yield. Factors such as preceding crop, rice genotype, planting density, residue management, soil structure permeability, tillage method and time of nitrogen application influence nitrogen uptake in rice. Under puddling conditions nitrogen is lost mainly by nitrification[4], denitrification[5] and diffusion (Fageria *et al.,* 2011 in Tahir *et al.,* 2019). Nitrogen has an important role in rice. Yield is significantly increased with application of site-specific nitrogen (Ren *et al.*, 2020). Nitrogen application has also been reported, improving nutritional and processing quality of rice, but excessive application negatively affects quality characteristics, such as increasing rice chalkiness as well as worsening cooking and eating qualities (Li *et al.*, 2019).

Rate, method and time of nitrogen application: Nitrogen should be applied on the basis of site-specific testing and DoA recommendations. The rate of nitrogen application depends on soil fertility, previous crops cultivated, organic manure application, and availability of water, crop management and soil chemical and physical properties. Sandy soils need more nitrogen due to high losses of nitrogen through leaching; therefore, high nitrogen application in split doses is recommended (Tahir *et al.,* 2019). Researchers have conducted various field experiments on nitrogen application to rice crop. As reported by Pan *et al.*, 2012, maximum rice yield was obtained with the split application (30 percent as basal application, 20 percent at 10 DAT and 50 percent at 36 DAT, i.e. nearly at the panicle initiation stage) with the nitrogen application of 240 kg ha^{-1}. Some other research experiments have revealed that rice yield and yield characteristic positively responded to nitrogen application at 120 kg ha^{-1}. About 63 kg ha^{-1} (56 lbs $acre^{-1}$) of compound fertilizer or three tonnes of natural fertilizer (compost of cow-dung) is applied as a basal application. About 63 kg ha^{-1} (56 lbs acre-1) of urea and six bags ha^{-1} of compost should be mixed and applied at sowing time (Myanmar GAP guidelines, 2018).

[4] A process carried out by nitrifying bacteria, transforms soil ammonia into nitrates (NO_3–), which plants can incorporate into their own tissues.

[5] The loss or removal of nitrogen or nitrogen compounds specifically reduction of nitrates or nitrites commonly by bacteria (as in soil) that usually results in the escape of nitrogen into the air.

Spilt application of nitrogen is the best strategy resulting in lower nitrogen losses and increased nutrient use efficiency. Splitting of nitrogen can be increased in coarse textured sandy soils under flooded/irrigation systems or high rainfall areas as well as when the crop is of longer duration (Thiyagarajan and Gujja 2012). With urea deep placement (UDP) technology, rice yield can be improved by at least 18 percent in the wet season and 28 percent in the dry season compared with broadcasting urea at the same N rate. Yield increase with UDP is due to an increase in nutrient use efficiency (NUE). UDP can double NUE over urea surface-broadcasting practices (Aung *et al.*, 2017).

The application of N in three split doses at the stages of before tillering, maximum tillering stages and stem elongation period is recommended. Therefore, one third of the total N should be broadcasted as a basal application at final land preparation. The remaining one third at tillering and another one third at stem elongation period should be deep placed, preferably at five to 10cm depth in the soil to reduce N losses (Aye, 2014).

Nitrogenous fertilizers: Commonly available sources of nitrogen as chemical fertilizers are, urea with 46 percent nitrogen available in granules or crystalline form, ammonium nitrate with 34 percent nitrogen in solid granular form, and ammonium sulphate with 21 percent nitrogen and 24 percent sulphur (*Fertilizers and their Use, Agriculture Extension Service, University of Tennessee, the United States of America*) and calcium ammonium nitrate (21 to 27 percent N, 8 percent Ca) (IFDC, 2018). ***Deficiency symptoms:*** The major deficiency symptoms of nitrogen in rice are the following:

- The plants appear stunted, thin and spindly with pale to yellowish appearance of leaves, manifesting first on the older leaves.
- The leaves become chlorotic and finally become necrotic (die).
- Reduced number of tillers and grains.

Conditions favoring deficiency: Certain environmental and soil conditions favor nitrogen deficiency such as:

- soils having low organic matter;
- insufficient and inappropriate application of nitrogen:
- soil cultivated continuously with exhaustive crops with little or no replenishment of nitrogen from organic and inorganic sources;
- in case of heavy rainfall resulting in increased nitrogen losses;
- soils which remain submerged for a long time; and
- acidic soils having a pH below 6.0 and alkaline soils having a pH above 8.0.

Integrated nitrogen management: In order to overcome nitrogen deficiency, the following measures should be taken:

- Soil testing for ascertaining the soil available nitrogen and site specific application of the nutrient from organic manures, bio-fertilizers, nitrogenous fertilizers, especially slow release nitrogenous fertilizers, such as sulphur-coated urea or urea super granules in a basal dressing before planting.
- Top dressing of soluble nitrogen fertilizers such as urea in two to three split doses. Nitrogen can also be applied through foliar application for quick recovery at two percent weight per volume (w/v) solution with repetitive application at 10 to 15 days interval until the symptoms disappear.
- Induction of legume crops in rice-based cropping systems.

Figure 47. Nitrogen-deficient leaf and a normal leaf.

Figure 48. Nitrogen-deficient crop with a close view

Phosphorus

Phosphorus is an important macronutrient essential for various biochemical processes in plants and needed for energy transfer from one part to another. Phosphorus is important for rice early maturity, improving straw strength and crop quality as well as inducing resistance to diseases (Tahir *et al.*, 2019). Phosphorous is also essential for root development, tillering, early flowering, and ripening. Phosphorus is mobile within the plant, but not in the soil.

Rate, method and time of phosphorus application: Phosphorus fertilizers should be applied on site-specific basis after soil testing for soil phosphorus and in line with technical recommendations of DoA. The application of phosphorus also depends on soil structure, previous crop cultivated, losses of phosphorous due to erosion, flooding and other abiotic stress factors. Phosphorus fertilizers should be fully incorporated into the soil during puddling or top dressing of the entire dose at 10 to 15 days after direct seeding.

Various experiments have revealed significant effects of phosphorus in increasing yield. Application of 60 to 90 kg P_2O_5 ha^{-1} was found beneficial for higher rice yield. Phosphorus deficiency has been reported on very acidic or very alkaline soils (Baskar *et al.,* 2 000). Water-soluble superphosphate fertilizers are more effective than other phosphate fertilizers in most of the paddy soils. However, superphosphate fertilizers are not easily taken up by the plants grown in acid soils due to the fixation problem in such soils. Therefore, rock phosphate should be applied as a source of phosphorus to paddy grown in acid soils. Phosphate fertilizer should be broadcasted as a basal application at final land preparation prior to transplanting. If there is no location specific fertilizer recommendation for high yield varieties, then at least 1.75 kg ha^{-1} P_2O_5 should be applied after harvesting of 1tonne paddy ha^{-1} if all the straws remains in the field and are incorporated into the soil. If all the straws are removed from the field, 15 kg ha^{-1} P_2O_5 should be applied in the field (Aye, 2014).

Phosphate fertilizers: Commonly available phosphate fertilizers are diammonium phosphate (DAP) with 18 percent N and 46 percent P_2O_5 available in granular form, triple super phosphate (TSP) with 46 percent P_2O_5 available in solid granular form and single super phosphate (SSP) with 20 percent available in sold granular form. Phosphate fertilizers, however, should be applied on site-specific basis for ensuring their effective utilization by the plants (*Fertilizers and their Use, Agriculture Extension Service, University of Tennessee, the United States of America*).

Deficiency symptoms: The following phosphorus deficiency symptoms are observed in rice crop:

- Plants become dark green with narrow, short and erect leaves with deficiency appearing first on old leaves.
- The plants are generally stunted with reduced tillers.
- Plant stems are thin and spindly having retarded growth with drastic reduction in panicles and grain per panicle.
- Maturity of the crop is delayed.
- Sometimes red and purple colours may develop on affected older leaves which start from leaf margins and later cover the entire leaf.
- Leaves become chlorotic and necrotic if deficiency persists for a long time.

Conditions favoring deficiency: Phosphorus deficiency occurs under the following conditions:

- Soil exhausted with intensive and continuous cropping with no appropriate nutrient replenishment.
- Phosphorus deficiency is also observed in soils treated with excessive liming giving rise to immobilization of the nutrient in calcium phosphate form.
- Soils are low in organic matter and have coarse texture besides having little phosphorus reserve.
- Highly weathered, clayey, acid upland soils, where phosphorus fixation capacity is remarkably high.
- Calcareous, saline and sodic soils.
- Excessive use of nitrogenous fertilizer with insufficient application of phosphate fertilizer.
- Acid soils having a pH below 6.0 and alkaline soils having a pH between 7.5 and 8.5.

Correction of deficiency through integrated nutrient application: Phosphorus deficiency can be overcome through the following integrated nutrient application regime on site-specific basis:

- Conducting soil analysis for ascertaining the level of phosphorus deficiency.
- Application of soil test based application of phosphorus from sources like:
  - organic manures;
  - phosphate-solubilizing microbial cultures or phosphate fertilizers; and
  - in deficient standing crop, soluble phosphate fertilizers, such as ammonium phosphate with irrigation water.

Figure 49. P-deficient leaf showing purpling on the margins

Figure 50. Close-up of a leaf showing purpling

Figure 51. Leaf showing advanced stage of pigmentation due to P deficiency

Potassium

Potassium is the third essential nutrient for plant growth, after nitrogen and phosphorus. Potassium is an integral element in activation of enzymes for plant metabolism, inducing resistance to biotic (diseases) and abiotic (cold, water stress/drought, heat, high light intensity and frost) stresses. Potassium is also important in enzyme activation besides its role in protein synthesis, plant water regulation, stomatal movement and phloem transport. Potassium improves root growth, plant vigor and make the plants more lodging resistant. The element is mobile in plants as well as in soil (IRRI Rice Knowledge Bank). Potassium has been reported as a limited nutrient in areas where high yield and intensive rice farming is practiced. In case of potassium deficiency, water use, and nitrogen efficiency is also greatly reduced (Mikkelsen and Roberts, 2021).

Rate, method and time of potassium application: The application rate of potassium should be decided based on soil tests for potassium soil status, previous crop cultivated and soil physical and chemical properties as well as previous organic and inorganic potash fertilizers applied to rice. To ensure site-specific application of potash fertilizers, recommendations of local DoA experts should be followed. Being a mobile nutrient, potassium can be applied to rice as foliar application as well as application through soil. As reported by Ali et al (2007), the application of K_2SO_4 at the rate of 50 kg ha^{-1} resulted in maximum rice yield of 387 4 kg ha^{-1}. In case small rate of potash fertilizer is intended for application, the full dose of fertilizers should be incorporated before the last soil puddling and before transplanting or the fertilizers can also be top dressed within 10 to 15 days after direct seeding. When the recommended potash fertilizer dose is more than 30 kg ha^{-1}, then 50 percent should be applied as basal dose while the remaining 50 percent should be applied at early panicle initiation stage. In case of sandy soils, potash fertilizer should be applied at least in two spilt doses due to high rate of leaching losses. Application of potash fertilizers at flowering stage increases resistance to lodging (IRRI Rice Knowledge Bank). DAR (2019) also reported that two split doses of K_2O - 50 percent at the time of transplanting and 50 percent at tillering stage resulted in four percent yield increase on sandy soils. Potash should be applied in two split doses, i.e. 50 percent at final land preparation as basal application and 50 percent at stem elongation period, which can be broadcasted (Aye, 2014).

Potash fertilizers: Commonly available potash fertilizers are potassium chloride with 60 percent potassium and available in solid granular form, muriate of potash (MoP) with 60 percent K_2O potassium sulphate with 50 percent potassium and 18 percent sulphur available in solid granular form, and potassium nitrate with 13 percent nitrogen and 44 percent potassium available in granular or crystal solid form (*Fertilizers and their Use, Agriculture Extension Service, University of Tennessee, the United States of America*).

Deficiency symptoms: In case of severe potassium deficiency, the following symptoms are observed, especially in fields intensively and continuously cultivated with rice and less or no application of organic or inorganic potash source:

- Plants appear stunted and dark green with yellowish brown leaf margins and/or older leaves with necrotic tips and margins;
- Deficiency of potassium is sometimes confused with rice disease caused by a virus called Tungro disease[6], but it should be noted that the disease only occurs in patches, not in the entire field. The disease symptoms manifest as yellow and orange color leaves with stunted plants;
- Deficiency symptoms appear on leave at the late growth stages;
- Deficiency also results in unhealthy or black roots; increased lodging and higher level of unfilled grains and ultimately lower grain weight and grain quality.

Conditions favoring deficiency: The following conditions create conducive conditions for potassium deficiency:

- Soils which are inherently poor in potassium especially formed from parent materials.
- Soils have low content of organic matter.
- Imbalanced use of fertilizers, especially excessive use of nitrogenous and phosphate fertilizer without potash fertilizer.
- Soils which are highly weathered and acid soils with a pH below 6.0.

[6] Rice Tungro disease is caused by the combination of two viruses, transmitted by leafhoppers with symptoms such as leaf discoloration, stunted growth, reduced tiller numbers and sterile or partly filled grains.

- Poorly drained soils in which potassium uptake is negatively influenced by H_2S, organic acids and excessive concentration of Fe^{++};
- Rice where high yielding rice varieties such as hybrid rice cultivars are cultivated with less application of potash.

Correction of deficiency through integrated nutrient application: The following methods should be used to overcome potassium deficiency if evidenced from soil analysis in rice field:

- Addition of organic manures (compost, FYM, green manuring, kitchen manures) before planting and during land preparation.
- The recommended doses of potash source fertilizers should be applied such as potassium chloride, potassium nitrate, potassium sulphate or a compound fertilizer such as N:P:K to the soil at planting.
- In order to overcome potassium application and increase its use efficiency, apply in split application as two to three split doses with first application at planting, second at panicle initiation , i.e. 40 to 50 DAT and third/final application at 60 to 70 DAT.
- In case potassium deficiency is observed in the standing crops, then apply soluble potassium chloride, potassium nitrate or potassium sulphate with irrigation water.

Figure 52. Leaves with yellowish brown necrosis

Figure 53. Close view of leaves with yellowish brown necrosis

Compound fertilizers (NPK)

Smallholder farmers usually apply compound fertilizers with a different nutrient ratio of the three major nutrients (NPK) due to their difficult access to soil analysis, cultivation of multiple crops and financial constraints. Blended fertilizers result in high yield but are not addressing other nutrients, especially micronutrient deficiency in the soil. Different blends of NPK fertilizers are available in Myanmar, i.e. 20:20:10 (NPK), 15:15:15 (NPK), 20:10:05 (NPK), 30:10:10 (NPK), 20:20:10 (NPK), 15:15:15 (NPK), 15:10:05 (NPK), for various types of soils and crops cultivated. However, it is highly important to apply compound fertilizers on site specific, soil test basis to avoid soil toxicity, optimize the nutrient requirement and uptake in increasing the yield of rice, and benefits of interactions between the organic and inorganic fertilizers as well as increased fertilizers use efficiencies. In case the soil tests are not available, the compound fertilizers of different grades should be applied with a ratio of 150:50:50 (NPK) for short duration varieties under dry and wet conditions (TNAU).

The registered products should only be purchased from licensed suppliers and used for crop production. The fertilizers and soil additives used should be free from chemical and biological contaminations that may be harmful on and off-site.

2.8.1.1.2. Essential and micronutrients

Micronutrients are important for rice like other cereal crops, but certain micronutrients are more critically required for rice productivity and nutritive value. Successful micronutrient management in rice depends on application of the nutrient amount, form, mode and timings, especially when multiple nutrient stresses, synergism and antagonism are expected. Both deficiency and excess of micronutrient adversely affect rice growth and plant development. Following are the important micronutrient and strategies for their effective management in rice crop.

Zinc (Zn): Zn is the most important micronutrient, and its deficiency is commonly observed in wetland rice, sometimes coupled with phosphorus deficiency. Zn availability is impaired under the submerged conditions when there is increased availability of Ca, Mg, Cu, Fe, Mn and P (Das, 2014). Deficiency of Zn affects first younger or middle aged leaves (Das, 2014). Zinc deficiency mainly occurs when soil pH is high and there is high organic matter in soil or calcareous soils with high bicarbonate content and intensively cropped soils. Zinc deficiency is caused by extended periods of submerged conditions. Deficiency symptoms appear on young or medium-aged leaves. The disorder normally caused by Zn deficiency is called *Khaira* disease in which leaves discoloration, restricted growth, plant stunting and leaves with chlorotic midrib occur (Zhu *et al.,* 2004). If soil tests show Zn deficiency, then apply 25 to 30 kg zinc sulphate ha^{-1}. If deficiency appears in the standing crop, spray five kg of zinc sulphate plus 2.5 kg of unslaked lime in 800 liters of water at 20, 30 and 40 days after planting. Zinc fertilizers should not be mixed with phosphate fertilizers (Kumar and Sharma, 2013).

Research findings from Myanmar revealed that 3 lbs acre^{-1} of zinc sulphate as a basal application resulted in increasing 10 to 15 percent of grain yield of paddy (DAR, 2019).

Figure 54. Zinc deficiency with brown blotches on leaves

Figure 55. Plant showing Zn deficiency symptoms on lower leaves

Figure 56. Close-up of a Zn deficient leaf at advanced stage

Figure 57. Zinc-deficient rice plant

Iron (Fe): Iron (Fe) deficiency is common in rice especially in upland high pH aerobic soils while its toxicity is also a constraint in lowland production areas. Iron deficiency manifests chlorosis between the veins of leaves and deficiency appears first on the younger leaves (Zu *et al.*, 2012). Other deficiency symptoms include interveinal yellowing and chlorosis of emerging leaves, less dry matter production, plant stunting and narrow leaves. The main reasons for iron deficiency are low concentration of iron in upland soils, coarse textured soils, lowlands with less organic matter and increased *Rhizosphere* pH. Deficiency of iron can be corrected with the application of 25 kg $FeSO_4$ ha^{-1} between the rows (Chaudhary and Wallace, 1976).

Figure 58. Zinc-deficient rice plant

Figure 59. Interveinal chlorosis on a young leaf of iron deficient plant

Figure 60. Leaves completely devoid of chlorophyll

Figure 61. Leaf showing papery white appearance

Boron (B): Boron is an essential micronutrient for rice and plays an important role in the development of new cells in meristematic tissues, translocation of sugars, starch and phosphorus as well as essential for cell wall formation. Deficiency of boron results in low plant height. Its deficiency also causes failure to produce panicles when deficient at panicle initiation stage. Tips of the newly emerging leaves are white and rolled. In case the deficiency is verified through soil test, the boron compounds such as borax, boric acid or boron in chelated form can be applied. Application of two to three kg ha^{-1} of boron compound should be applied in clayey soils and three to five kg ha^{-1} in sandy soils. Excessive application of boron causes toxicity to the crop. (Kumar and Sharma, 2013).

Figure 62. Boron-deficient rice plant

Figure 63. Leaf tip tends to roll

Figure 64. Rolled white tip of affected rice leaf

Figure 65. Advanced stage of leaf damage by boron deficiency

Manganese (Mn): Manganese deficiency is common in upland rice, degraded soils, soils rich in iron, those having high accumulation of H_2S, acid sandy and acid sulphate soils. Deficiency can be corrected by the application of farmyard manures, acid forming fertilizers (do not use urea) and through application of $MnSO_4$ or MnO at two to five kg ha^{-1} through multiple application (Chaudhry and Wallace, 1976).

Figure 66. Manganese deficiency in rice

Figure 67. Manganese toxicity in rice

Sulphur (S): Sulphur is also an important micronutrient for rice and plays a vital role in aminoacid and protein synthesis, enzymatic and metabolic activities in plants. Sulphur deficiency is common in areas where oilseed and pulses crops are intensively cultivated (Kumar *et al.*, 2009). Moreover, soils deficient in organic matter, light textured soils, soil exhausted by intensive cropping having less replenishment with sulphur and acid soils having a pH below 6.0 show sulphur deficiency (Kumar and Sharma, 2013). Rice crops require sulphur in various quantities according to nitrogen supply to the plant. If sulphur becomes a limited nutrient, addition of nitrogen does not change rice yield and plant protein level. Deficiency in early growth stages, tillering capacity and yield is negatively affected (Lefroy *et al.*, 1994). The plants remain stunted, thin and spindly with pale yellow leaves with maturity delayed. Young leaves become dull or bright yellow in appearance while the old leaves remain green. In case of severe deficiency, young leaves become necrotic at the tips. Sulphur deficiency can be corrected through application of elemental sulphur or gypsum or application of aluminum sulphate, potassium sulphate with irrigation water (Kumar and Sharma, 2013).

Figure 68. Sulphur-deficient rice plants

Figure 69. Sulphur-deficient rice crop

Figure 70. Deficient plant showing the pale youngest yellow leaf

Figure 71. Sulphur-deficient leaf (left) compared with a healthy leaf (right)

Type, method, rate and time of manures and fertilizers should be decided on sits specific basis after soil test with recommendations of DoA

Fertilizers, manures and soil additives

Refer to Annex 1 practice 1.4 and 1.6.3 of Myanmar GAP guidelines 2018, Annex 2.1 practice 2.1.3, 2.1.9 Annex 2.2 practice 2.2.3, 2.2.7, 2.2.8, 2.2.13, Annex 2.3 practice 2.3.3, 2.3.4, Annex 2.4 practice 2.4.1, 2.4.3, 2.4.5 of ASEAN GAP guidelines for further guidance.

Record keeping

The fertilizers and soil additives used for GAP crop before and after sowing, soil test result, dose, method and timings of chemical fertilizers application should be recorded as per Annex 3 (Form- 1. Fertilizer Application; 1 to 4 and Form.2; Fertilizers and Soil Additives; 1 to 6).

Think responsibly and act judiciously while adding chemicals to the soil: Use the right fertilizers source with the right rate, time and method of placement:

- Soil management is key to addressing climate change.
- Make decisions on evidence-based soil nutrient management.
- Judicious application of fertilizers increases production.
- Improve and diversify farm profitability.
- Protects environment and ensures farm resource sustainability.

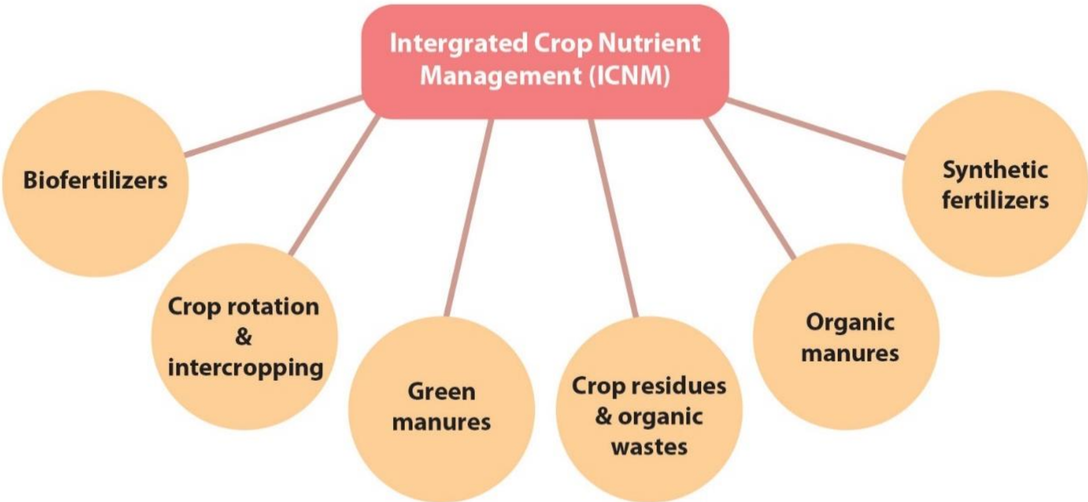
2.8.1.2. Organic manuring

Organic manuring is a climate smart approach for safe, sustainable, resource efficient and ecofriendly system of rice production and a viable step towards climate smart agriculture. Most farmers are using farmyard manure as a mixture of animal wastes such as cow-dung (solid or slurry form), goat manure, chicken manure, plant residues and kitchen wastes. Using organic and inorganic manures together is known as integrated nutrient management (INM) approach, which is a sustainable and ecofriendly approach of crop nutrition to overcome nutrient deficiency and low nutrient retention capacity in soils. Organic manures are a rich source of nitrogen and other essential micronutrients. Poultry manures, FYM composts and crop residues are of immense importance in climate smart and climate resilient agriculture and food systems. Organic manures, besides being a significant source of macro- and micronutrients also improve physiochemical properties of soil such as soil porosity, infiltration rate, total carbon, water holding capacity and action exchange capacity, reducing bulk density, checking soil erosion and leading to increased availability of plant nutrients through mineralization. Use of organic materials as mulch is an important low-cost farm input to control or minimize weed infestation. Proper method, application rate, and time of inorganic fertilizer along with organic manure not only decrease nitrification rate but also play a key role in increasing crop productivity by increasing nitrogen use efficiency (Khan *et al.*, 2009).

To enhance environmental quality and ensure sustainability in food production, make efficient use of nonrenewable on-farm resources in an integrated and synergistic manner.

Organic manuring is a climate smart approach for safe, sustainable, resource efficient and ecofriendly system of rice production and a viable step towards climate smart agriculture. Most farmers are using farmyard manure as a mixture of animal wastes such as cow-dung (solid or slurry form), goat manure, chicken manure, plant residues and kitchen wastes. Using inorganic and inorganic manures together is known as the integrated nutrient management (INM) approach which is a sustainable, and ecofriendly approach of crop nutrition to overcome nutrient deficiency and low nutrient retention capacity in soils.

Figure 72. Integrated crop nutrient management model



Source: Elaborated by the author

Besides application of inorganic manures, organic manures such as farmyard/animal manure, mulching, crop residues and green manuring must also be incorporated in the cropping systems in rice-cultivated areas to prevent micro- and macronutrient deficiencies. The main types of organic manures are farm and animal manures, crop residues, green manures, biogas slurry, and biodynamic compost, vermicompost, which if properly prepared and applied, provide the best medium for plant growth and nutrient mobility and uptake by the plant nutrients.

Organic manuring: A climate smart approach for safe, sustainable, resource efficient and ecofriendly system of rice production and a viable step towards climate smart agriculture	
Refer to Annex 1 practice 1.4 and 1.6 of Myanmar GAP Guidelines and Annex 2.1, practice 2.1.3, 2.1.9 and figure 67, Annex 2.2 practice 2.2.3, 2.2.8, Annex 2.3 practice 2.3.4, figure 73, Annex 2.4 practice 2.4.3 for further guidance	***Record keeping:*** The types, dose, method and timings of organic manures, chemical fertilizers (macro- and micronutrients) should be recorded as per Annex 3 (Form 1. Fertilizer Application; 1-4, Form 2, Fertilizers and soil additives 1-6).
The chemicals obtained, stored, used, application and disposals of chemicals are systematically handled and recorded as per Annex 3 (Form.1. Pesticides/Fungicides Application; 1to 4 and Form.2. Agrochemicals and Other Chemicals; 1 to 12).	

2.8.1.2.1. Farm yard manures (FYM)

FYM are manures collected and decomposed, consisting of both dung and urine with associated litter and remains in the animal sheds. Composting of farmyard manure increases its value in terms of nutrient recycling capacity, texture, friability and absorptive capacity. Application of fresh farmyard manure should be avoided not only due to low nutrient contents but also due to a source of insects' pests and other potential toxicity to the plants. Animal urine is a valuable part of animal manure and contains appreciable amount of nutrients. The animal manure mixture (dung and urine) should be collected and trenched in a pit of the size six to 7.5m length, 1.5 m to 2.0 m width and 1.0 m deep for decomposition. After filling the pit, the top should be tightly covered through plastering to enhance decomposition and nutrient loss. The manure becomes ready after four to six months for application to the crops at the time of sowing/land preparation. Application of farmyard manures depends on soil fertility status and other crop management practices.

Table 6. Average values for moisture and nutrient content of farm animal manures

Source	Portion	Percent	Moisture Content	Nitrogen (percent)	Phosphorus (percent)	Potassium (percent)
Horse	Manure	80	75	0.55 (0.50–0.60)	0.33 (0.25–0.35)	0.40 (0.30–0.50)
	Urine	20	90	1.35 (1.20–1.50)	Trace	1.25 (1.00–1.50)
	Mixture	—	78	0.7	0.25	0.55
Cattle	Manure	70	85	0.40 (0.30–0.45)	0.20 (0.15–0.25)	0.10 (0.05–0.15)
	Urine	30	92	1.00 (0.80–1.20)	Trace	1.35 (1.30–1.40)
	Mixture	—	86	0.6	0.15	0.45
Swine	Manure	60	80	0.55 (0.50–0.60)	0.50 (0.45–0.60)	0.40 (0.35–0.50)
	Urine	40	97	0.40 (0.30–0.50)	0.10 (0.07–0.15)	0.45 (0.20–0.70)
	Mixture	—	87	0.5	0.35	0.4
Sheep	Manure	67	60	0.75 (0.70–0.80)	0.50 (0.45–0.60)	0.45 (0.30–0.60)
	Urine	33	85	1.35 (1.30–1.40)	0.05 (0.02–0.08)	2.10 (2.00–2.25)
	Mixture	—	68	0.95	0.35	1
Poultry	Mixture	—	55	1.00 (0.55–1.40)	0.80 (0.35–1.00)	0.40 (0.25–0.50)

Source: Van Slyke, L. L. 1932. Fertilizers and crop production. Orange Judd Publ. Co. Inc., New York.

According to the local Myanmar Research findings, a three to five year continuous application of 10 tonnes ha^{1} of natural or organic fertilizers (such as cow-dung, sesame straw, bio composer [compost of sugarcane press mud] and farmyard manures) resulted in a grain yield of paddy which is equivalent to that of the fertilizer treatment - 120 lbs ha^{-1} of Urea, 28 lbs ha^{-1} of Tsuper, 28 lbs ha^{-1} of Potash and 300 lbs ha^{-1} of gypsum (DAR, 2019).

Table 7. Average values for nutrient content of rice straw, rice husk, rice husk ash and cow-dung (Kg ton^{-1})

Source	N	P	K	Mg	S	Si
Rice straw	5.0 – 8.0	0.7 – 1.2	11.6 – 16.6	-	0.5 – 1.0	40 – 70
Rice husk	5.0 – 10.0	0.6 – 0.9	4.0 – 4.9	1.0 – 3.0	1.0	10 – 20
Rice husk ash	-	3.2 – 4.6	5.5 – 15.0	1.2 – 3.0	-	65 – 80
Cow-dung	6.0 – 6.4	1.5 – 1.8	6.6 – 7.3	0.4 – 1.3	-	-

Source*:* Aye, T. M. 2014. Field Handbook: 4R Nutrient Management of Rice in Myanmar. International Plant Nutrition Institute, Southeast Asia Program (IPNI SEAP), 16 pp.

Rice farmers should use not only chemical fertilizers but also organic fertilizers such as rice straw, farm animal manures and composts as a source of crop nutrients. Burning rice straw resulted in losses of almost N, 25 percent of P_2O_5, 20 percent of K_2O and (5 – 60) percent of sulphur respectively (Aye, 2014).

Intensive cultivation of rice growing lands without sustainable soil fertility management results in soil degradation. Soil physical and chemical characteristics are impaired due to increase in soil acidity, alkalinity/sodicity, soil compaction, and excessive, injudicious application of chemical fertilizers, pesticides and weedicides, which in turn negatively influence soil biodiversity. Less use of organic manures, less crop rotation and site-specific fertilization application further deteriorates the soil fertility, structure and texture. In order to sustainably manage soil fertility, organic manures should be used as they are rich in macro- and micronutrients as well as a rich source of organic matter. Application of the right quantity of well-decomposed farmyard manure mitigates soil degradation and improves crop productivity and quality. Rice crop is highly responsive to farmyard manure application (Satyanarayana *et al.*, 2002).

Organic manures, especially well decomposed farmyard manure application, increased rice productivity as well as improved soil health (Siavoshi *et al.*, 2011). As reported by Myint *et al.*, (2010), the application of organic manures supply nutrients needed by the plant, including micronutrients which improve soil physical and chemical properties and improve microbial activities and soil biodiversity, besides being an important source of inorganic phosphorus from mineralization (Sudarsono *et al.*, 2014). Application of seven tonnes of well-decomposed farmyard manure can increase rice yield up to four to six tonnes ha^{-1} (Chettri *et al.*, 2003).

Avoid application of fresh FYM: Application of fresh farmyard manure should be avoided not only due to low nutrient contents but also due to a source of insects' pests and other potential toxicity to the plants.

Reduce contamination through Best Management Practices of FYM composing

Protect stored manure (and compost) from rain, and safely manage the run-off of effluent from compost heaps to avoid contamination of adjacent soils, work areas and waterways.

Use effective barriers to areas of composting to reduce the likelihood of complaints and contamination. Apart from the visual effect, barriers can also help to filter and thin out odors.

Figure 73. Well decomposed FYM

Figure 74. Compost piles in various stages of development

2.8.1.2.2. Bokashi compost

Bokashi is a Japanese word meaning, "fermented organic matter" which was first developed in early 1980s at the University of Ryukyus, Japan. The method encompasses layering of kitchen scraps (vegetables and fruits, meant and dairy scraps) with a Bokashi inoculant in a specially made bucket. The inoculant used in Bokashi contain wheatgerm, bran of wheat or sawdust mixed with EM and molasses. The bran is food for the microorganism similar to those organisms found in the soil. Application of combined application with NPK enhance the quality of sustainable soil fertility management (Lasmini *et al.*, 2018).

Step in preparing Bokashi compost (OISCA, DoA Myanmar)

1. Place a four to five inches layer of cow-dung and chicken droppings. (stage 1)
2. Cover on cow-dung layer with rice bran. (stage 2)
3. Thoroughly mix Bokashi seed (0.5 Kgs) with a small amount (3 Pyi = 2.56 litres) of rice bran.
4. Then, spread Bokashi seed on rice bran layer.
5. Then add Sesame oil cake or dry fish powder. (stage 3)
6. Then add ash or Rice husk charcoal (stage 4)
7. Then add silt on Rice husk charcoal
8. Mix thoroughly the composting materials and sprinkle water on to it with a rate of 20 litre water 100 kg^{-1} of composting materials and mix thoroughly again. (stage 5)
9. Take a small handful of the mixture and knead it. If the mixture is equally damp and slightly sticks to itself (it cannot be moulded), it is ready to make a Bokashi compost. (stage 6)
10. The mixture is piled up to (1–2) feet height evenly and slightly covered the top with a layer of straw or dried grass or old tarpaulin (stage 7 – 8)
    - Turn the compost pile once a day depending on the temperature. If it is needed, stir the compost pile to keep the temperature not to be more than at 50–55 °C until 5 days after piling.
    - Compost can be harvested and used during 7–10 days after piling.

Bokashi preparation steps

Figure 75. Bokashi preparation-placing a 4–5 inches layer of cow-dung

Figure 76. Bokashi preparation – covering cow-dung layer with rice bran

Figure 77. Bokashi preparation – spreading sesame oil cake

Figure 78. Bokashi preparation – spreading rice husk charcoal

Figure 79. Bokashi preparation – sprinkle water on Bokashi

Figure 80. Bokashi preparation – mixing thoroughly the composting materials

Figure 81. Bokashi preparation – covering with tarpaulin

Figure 82. Bokashi compost making in Magyi Village using molasses, rice bran, rice vinegar, etc. to facilitate the decomposition process

- Be careful and keep the compost not to be in direct sunlight for a long time before use.
- For later use, air-dried compost can be stored in the polyethylene bags or containers. Moisture during storage should be controlled to prevent development of mold, nor to allow moisture for decreasing enough to leave the compost dry.
- Compost can be used by mixing with chicken manure/swine manure/cow dung for soil fertility improvement by increasing the number of effective microorganisms.

To mitigate the toxic effects of salts on rice crop and improve available and applied nutrient use efficiency in areas of salinization, application of organic matter such as Bokashi compost is beneficial. As reported by Sulistiani and Mufriah (2013) that application of 12 toones ha^{-1} of Bokashi compost increased grain weight and yield in rice under soil salinity conditions.

2.8.1.2.3. Biodynamic / aerobic composting

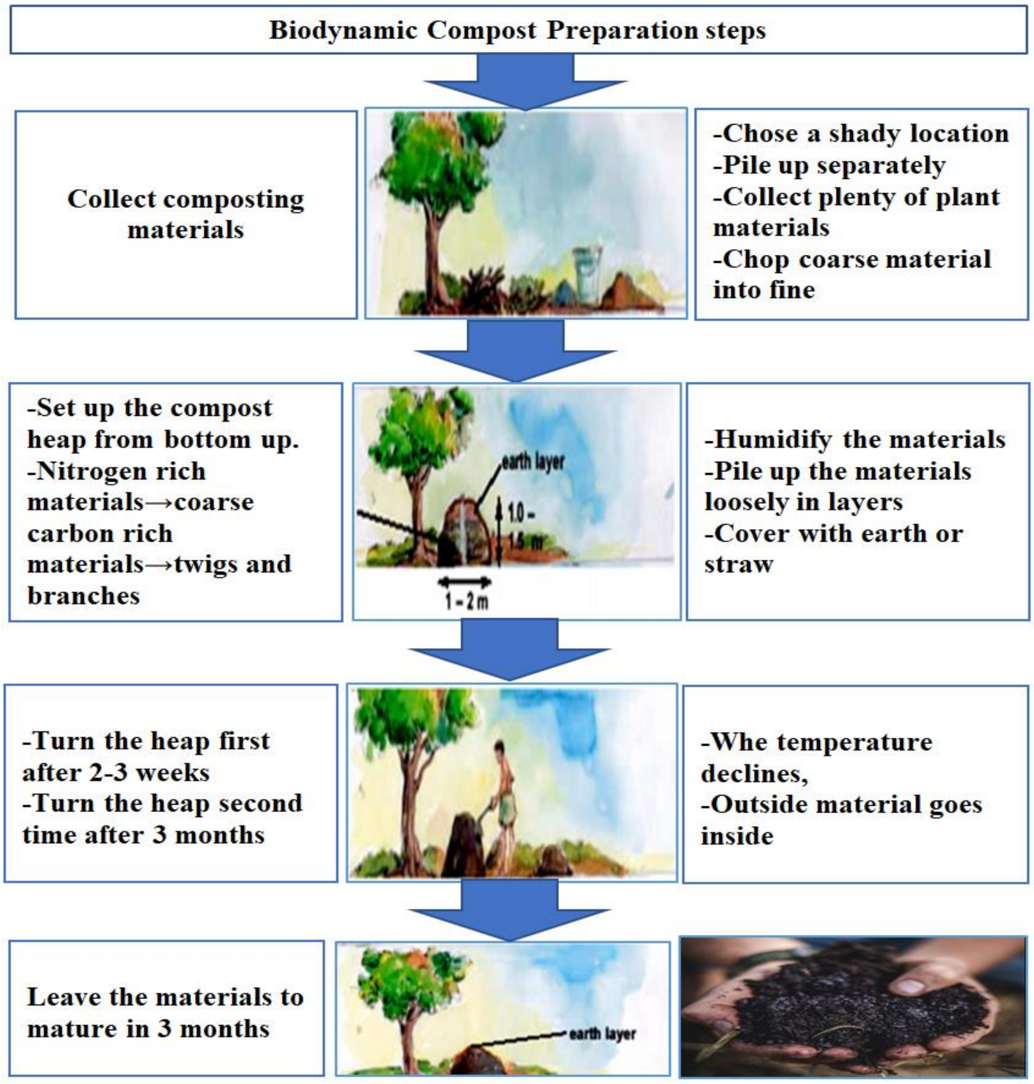
A number of climatic factors affect the quality of compost as the final organic fertilizer. Oxygen for aeration to encourage aerobic microbes' activity and thus enhancing decomposition of compost materials. Therefore, good aeration is particularly important for effective composting. Similarly, moisture is also necessary for microbial activity of microorganisms. The materials should have a moisture content of 40–65 percent. Temperature is an important factor determining the composition of compost. The initial temperature can go up to 20–45 °C and can further increase up to 50–70 °C with the microorganism.

Store manures disposal areas away from productions site, regularly monitor manures for odor and cover manure heaps with soil to minimize odor and reduce the risk of disease transmission, and pests build up.

To regulate the temperature, turning of compost is especially important. Compost can be ready for application to the crops in 6–8 months. To prepare quality biodynamic compost, ensure ventilation into the compost heap through punching a hole in the pile at many places or inserting a bamboo and withdraw them after some days. Keep on turning the compost to improve aeration 3–4 times during the maturation time. To further improve the quality of compost and enhance its fertility aspect and decomposition, inoculation with cost effective EM (Effective Microorganisms) such as fungi such as *Trichoderma sp* and *Pleurotus sp*. is important (Composting process and techniques, aerobic composting process-FAO).

Figure 83. Biodynamic compost making in Myanmar

Figure 84. Steps in compost making



Source: FAO. 2015. FAO training manual for Organic Agriculture. 2015.
https://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Compilation_techniques_organic_agriculture_rev.pdf

2.8.1.2.3. Vermicomposting

Vermicompost, which is also, called worm compost, and worm manure is decomposed materials broken down by some earthworms. The compost prepared with worms is rich in nutrients, improves soil fertility and acts as soil conditioner. The compost is a rich source of nutrients, improves soil microbial activities and also contains beneficial growth hormones. The application of vermicompost in rice crop gives beneficial results in terms of increased produce and improved nutrient use efficiency. Due to the declining soil fertility and nutrient losses, the use of organic manures is becoming popular. As reported by Bejbaruah et. Al. (2013), split application of vermicompost at different growth stages of rice, i.e. maximum tillering, panicle initiation and flowering, resulted in increased panicles (294 m^{-2}), improved grains per panicle (138), spikelets per panicle (142) and grain yield (3.91 t ha^{-1}), besides increased nutrient use efficiency (NUE). The research found that split application of vermicompost is also the most efficient method to reduce nitrogen losses. Vermicompost application is also an effective strategy for sustainable soil fertility management in case of high yield modern rice varieties. Farmers using vermicompost have reported reduced crop production cost and increased yield and water use efficiency.

Steps in preparation of vermicompost

Vermicompost can be prepared from biodegradable materials such as crop residues, weeds biomass, vegetables wastes, leaf litter, hotel and kitchen refuse, and waste from agroindustries and biodegradable waste of rural and urban wastes. Vermicompost also enriches microbial population and soil biodiversity, particularly fungi, bacteria and actinomycetes.

The following steps are involved in the preparation of vermicompost (Kaur, 2020).

Store the vermicompost in a proper place to maintain moisture and allow the beneficial microorganisms to grow		
Step 1	→	Collect wastes, shred, mechanically separate the metals, glass and ceramics and store the organic wastes.
Step 2	→	Predigest organic wastes using dry cattle dung and slurry for making it suitable for earthworm feeding.
Step 3	→	Prepare the bed for earthworms, for which a concrete base is required for the placement of waste for vermicompost preparation.
Step 4	→	Loosen the soil to allow the worms to enter it, as well as all the dissolvable nutrients (while watering).
Step 5	→	Collect the earthworms after vermicompost collection.
Step 6	→	Sieve the partially composted material to separate the fully composted material.
Step 7	→	Put the partially composted material into a vermicompost bed.
Step 8	→	Store the vermicompost in a proper place to maintain moisture and allow the beneficial microorganisms to grow.

The common earthworms suitable for vermicomposting of India, Malaysia and Myanmar origin are the Malaysian Blue worm (*Perionyx excavatus*), also known as Indian Blue worm, and the African Nightcrawler (*Eudrilus eugeniae*), as shown in the pictures below.

Figure 85. Sorting through a tray of Malaysian Blue (*Perionyx excavatus*) earthworms, also known as Indian Blues

Figure 86. African Nightcrawler (*Eudrilus eugeniae*) earthworms, note the distinctive blue sheen

2.8.1.2.4. Green manuring

Green manuring is the process of incorporating fresh, green crops into the soil by ploughing down, with the objectives to add organic matter to the soil, improve soil texture, structure and friability, besides adding nitrogen and other micronutrients to increase soil productivity. The incorporation of green manure crops into the soil also increases soil microbial activities for increased decomposition and thus improves the soil environment and biodiversity. The organic crop residues from green manure crops also stabilize soil structure, increase its water holding capacity and water infiltration, thus contributing to reduction of runoff in unlevelled and sloppy lands. The best time for incorporation of crop residues into the soil is at the beginning of the flowering stage when the plants attain maximum biomass and are highly succulent.

Crops for green manuring should be multipurpose, fast-growing and of short duration with a high nutrition accumulation ability. For the crops to be readily decomposed in the soil after incorporation, they should be herbaceous in nature and have the ability to be successfully cultivated as green manure crops under shaded, low moisture, and widely adapted to various ecological conditions. More importantly, the green manuring crops should not be an (alternate) host to any known insect pest. The suitable crops for green manuring in the project areas (CDZ) are cowpea, mungbean and *Sesbania aculeata*(FAO, 2019).

Practicing green manuring in combination with nutrient application have additive effects on yield and yield parameters of rice. The effect of different green manuring crops such as dhaincha, mugn and sun hemp resulted in a higher rice grain yield of 5 520 kg ha^{-1} (Duhan and Singh, 2002). Other growth characteristics, especially root length density (RLD) and improved conditions favourable for root growth and root distribution in the surface soil layers, can be found in summer fallow plots in wheat-rice cropping systems.

Process of green manuring

- The seeds of green manuring crops should be cultivated either in rows or broadcasted and chopped at the flowering stage when the crops have maximum nutrients stored and are highly succulent.
- The plants should be incorporated 25cm (10 inches) deep from the soil surface and be left for two weeks to decompose.

Figure 87. Green manure crops

Figure 88. Incorporation of green manure crops into the soil using tractor

Figure 89. Green manuring (*Crotalaria juncea*) for paddy cultivation, Myanmar

Figure 90. Incoporation of green manures into the soil (Green manures-Uses and types of green manures)

Figure 91. ***Sesbania rostrata*****, an efficient LGM in lowland rice cultivation area**

Figure 92. ***Sesbania rostrata*****, an efficient nitrogen fixer in lowland rice cultivation area**

Legume green manure (LGM) has growing acceptability and use to sustain lowland rice productivity, reduce production cost incurred on purchase of chemical fertilizers as well as lower other crop management costs. Cultivation of short duration LGM has beneficial effects to cover the substantial portion of the nitrogen needed by rice (Ladha *et al.*, 1988). LGM has an advantage over other organic manuring options in terms of being grown directly in the field and incorporated at the same site during land preparation or regular weeding operations. Moreover, LGM also reduces loss of nitrogen in the form of NO^{3-} through leaching while lowering nitrogen requirements for succeeding crops. As reported by Kolar et al (1993), Manguiat et al (1992), Meelu *et al.*, (1992), *Sesbania rostrata* as green manure grown for 40 to 60 days can substitute for 50–70 kg N ha^{-1} for lowland rice. Being an efficient LGM, *S. rostrata*[7] has been recommended as green manure in rice growing areas of Africa and Asia and is currently grown on about 500 000 ha in the Delta and the Central Plain of Myanmar (Mar *et al.*, 1992). Application of green manure (*Sesbania rostrata*) at a rate of ten tonnes ha^{-1} was equally effective as chemical fertilizer applied at the recommended rate of 40 kg N, 30 kg P_2O_5 ha^{-1} (Myint, 1993).

2.8.1.3. Soil additives and amendments

To improve soil biological, chemical and physical environment for increased rice production and produce quality, soil additives should be applied, especially in acidic, alkaline, clayey, loose, rocky, sandy, and waterlogged soils susceptible to erosion and sloppy soils. Addition of sand to heavy clayey soils improves soil aeration, drainage and root growth, resulting in high yield and quality produce. In case of soils with low pH (acidic), application of lime, and soils with high pH (alkaline), application of sulphur are recommended to neutralize soil pH. Application of organic manures such as compost application, green manuring, stubble mulching and peat mass addition also improve soil texture, aeration, water retention, and absorption of nutrients, especially locked up soil nutrients, and mitigate drought in arid and semi-arid areas. Important considerations while deciding about the use of soil additives are: a) how long the additive will last in the soil; b) existing soil texture; c) salinity status of the soil; d) plants sensitivity to salts; e) soil pH; and f) pH of the additives (Davis and Whiting, 2000). Additives should be applied on a site-specific basis after soil tests and in consultation with DoA.

What soil additives to apply to what type of problems soils?

Soil additives or soil conditioners are materials (organic and inorganic) applied to various types of soils to improve soil physiochemical conditions, i.e. reducing compaction, correction of soil pH, improving soil aeration, nutrient retention and mobility to the plant roots and moisture retention (Soil and soil amendment guide 2020).

apply organic composts	→	to enrich soil with nutrients, improve moisture retention and aeration
apply organic composts	→	to improve soil bio- and physiochemical conditions for better plant growth and increased nutrient use efficiency
apply lime	→	to raise soil ph and reduce soil acidity

[7] A small semi-aquatic leguminous tree, in the genus Sesbania.

apply sulphur-based additives	→	to decrease soil ph and increase soil acidity
apply gypsum	→	to improve aeration of compacted soil and drainage
apply vermicompost	→	to improve aeration and moisture retention

5.1.3.1. Gypsum (CaSO4.2H2O)

In view of the climate change induced problems of drought and growing soil salinity, farmers are coping through application of traditional knowledge and skills to adapt to the climate changes. Soils of the target regions are fragile and sensitive to degradation due to low soil fertility, deficient organic matter, salinity, high intensity but brief rainfall, causing soil runoff. Because of these problems, soils in the upland areas are exposed to water erosion. Progressive farmers practice water harvesting through traditional means, changing growing seasons to evade extreme weather events, applying gypsum to improve soil status and growing of drought resistant varieties (Zin *et al.*, 2019). Gypsum is a good soil additive rich in calcium and sulphur, as they are essential elements for plant growth and yield, besides increasing water-holding capacity of soil resulting in reduced erosion and improved soil aeration (Susan V. Fisk, 2019). Gypsum should be applied based on soil tests and identification of conditions for the recommended dose.

Figure 93. Rice production by using gypsum application in Boe Daw Taw village in Shwebo township

Growers are facing problems with their soils in irrigated agriculture, in general, and specifically in rice production through wet bed and puddling techniques. Soil becomes a yield-limiting factor if not properly managed and can affect the quality of production, given that rice is mostly cultivated in delta and coastal regions of Asia where the problem of salinity and sodicity adversely affect rice growth and productivity. It becomes important to take remedial and reclamation measures through addition of soil additives, especially gypsum in case of soil salinity. Climate change-induced water scarcity has also created constraints for rice production and decreased rice-growing areas. Use of gypsum for overcoming climate abiotic stress of salinity has been effective, especially under limited water conditions. Gypsum application alone or in combination with other organic and inorganic manures increases yield by reducing pH and increasing calcium and zinc supply. Gypsum applied with zinc proved most effective in increasing rice yield and zinc uptake (Khan *et al.*, 1991). As reported by Thein (2016), the application of cow dung manure at five tonne ha^{-1} was found most effective to correct soil conditions for increased productivity in the Sagaing region. It was also observed that gypsum application at two tonnes ha^{-1} proved to be the additive for the slightly saline, highly sodic soil of the Sagaing's Shwebo township.

CHAPTER 3 – CROP PRODUCTION REQUIREMENTS

3.1 Cropping patterns and systems

3.1.1 Crop rotation and intercropping

Crop rotation and intercropping are ingenious, low cost and sustainable climate smart techniques of weed, pests and diseases control, soil fertility, crop diversification and building farm resilience, increased ecosystem benefits and farm income. The techniques, especially intercropping, are climate smart way of building farm resilience, optimization of farm resources, increasing productivity, complementing income and minimizing risks.

3.1.1.1. Crop rotation

Crop rotation is a common and beneficial farming practice that promotes soil health by switching the crops grown on a plot of land every season or every few seasons. Crop rotation is considered as the most effective control measure for weedy rice and other problematic weed species. In rice-rice or rice-rice-rice cropping systems, one rice crop (preferably in the dry season) could be rotated with an upland crop such as corn (maize), mungbean, sesame, and soybean, etc. (Chauhan, 2013). Win *et al.*, 2020, also reported that the highest rice yield was obtained in the two-season crop rotation sequences (green gram-rice-black gram-rice, sesame-rice-cowpea-rice and sunflower-rice-sesame-rice) which were about two times higher compared with the one-season crop rotation sequences (rice-rice-chickpea-rice, rice-rice-black gram-rice, rice-rice-soybean-rice, rice-rice-cowpea-rice) and about three times higher compared with the continuous rice cropping sequence (rice-rice-rice-rice).

Farmers in CDZ decide for specific crop rotation because of certain considerations, such as:

- Using the same crop by changing the long duration varieties to short duration to avoid the risks of crop losses and market varieties preference.
- Switching to another crop, i.e. from groundnut to sesame tor other crops under circumstances such as high market demand, yield, and government incentives for certain crops.
- Scaling up of farm size due to high resources to buy more land, renting more acreage for cultivation, inheriting more land and scaling down of farm size due to labour shortage, diverting expenditure to other priorities, high debt and loss of farming income (Proximity, 2019).
- Some samples of crop rotation in paddy growing areas of CDZ are as follows:
    - paddy (monsoon) – green gram or sesame (pre-monsoon);
    - paddy (monsoon) – chickpea (winter) – sesame (pre-monsoon) and
    - paddy (monsoon) – black gram/green gram (winter).

Crop rotation and intercropping: Ingenious, low cost and sustainable climate smart techniques of weed, pests and diseases control, soil fertility, crops diversification and building farm resilience, increased ecosystem benefits and farm income.	
Principles of efficient crop rotation	
Deep rooted crops should be followed by shallow rooted crops such as chickpea, green gram and sesame;	Crops requiring heavy irrigation and intensive labour should be followed by less labour and irrigation intensive crops;
Crops sensitive to soil borne pathogens, parasite (Nematode) should be followed by Nematode tolerant crops;	Crops with perennial and invasive weeds should be followed by clean crops or those requiring clean cultivation in rows;
Non legume crops should be followed by legume crops; sesame should be followed by chickpea, green gram and groundnut for maintaining soil fertility;	Include short duration, fast growing fodders, and legume crop for green manuring, also as animal fodder;

Site-specific crop rotation *schemes should be devised and implemented in close consultation with DoA agriculture extension experts according to the local cropping sequences and patterns, but keeping in view the farm management practices, market demand, soil fertility, local soil characteristics, water availability, insect pests, diseases, weeds infestations and access to quality farm inputs.*

3.1.1.2. Intercropping and mixed cropping

Intercropping or mixed cropping is the cultivation of two or more crops on the same field in close proximity with or without an improved planting geometrical layout (beds, rows, strips/mixed) for increasing production, efficient utilization of environmental and physical resources, insects pests and diseases control, increased soil fertility, yield stability and crop risk minimization (Mousavi and Eskandari, 2011). Based on the nature of crops in terms of growing cycle, purpose of production and utilization and seasonality potentials, the intercropping schemes should follow intercropping annual crops with annual crops, annual crops with biennial crops and perennial crops with perennial crops.

Types of intercropping

- Row intercropping, where one or more crops are simultaneously cultivated in rows with variation in number of rows based on demand and local preferences. The ratio of rows of the crops may vary from 1:1, 1:2 and 1:3, etc.
- Mixed intercropping, where one or more crops are simultaneously cultivated with no fixed row or geometrical layout arrangements.
- Strip cropping, where one or more crops are simultaneously cultivated in stripes wide enough to allow independent cultivation.
- Relay cropping, where one or more crops are cultivated during the life cycle of each of the crop. Normally, a second crop is planted when the first crop has attained the reproductive stage but before the first crop is ready for harvest.

Benefits of intercropping

- Higher production with lower levels of external farm inputs, especially for small farmers where the growing cycle is short.
- Efficient use of farm resources as intercrops components are not in competition for the same niche (ecological nest) due to differences in morphological and growth characteristics but symbiotic in terms of legumes and non-legumes, shallow and deep rooted crops.
- Reduced pests, diseases and weeds, due to the crops species diversity in agriculture ecosystem because of which pathogen spreading is limited. Similarly, weeds also compete with main crops for water, light, nutrients, and space and sometimes cause allelopathic[8] effects on the main crop. Due to efficient utilization of farm spaces with useful and economic crops, weeds are controlled thanks to less availability of light, water, space, and nutrients being diverted to useful crops in intercropping.
- Stability and uniformity yield in case of small farmers having limited sources, income and stability yield. It is therefore important, that in case of failure of one crop, the second compensates for income and production, thus mitigating the risk of crop failure.
- Improve soil fertility and increase in nitrogen due to conservation of soil fertility in intercropping, as in crop rotation. *Rhizobium*[9] bacteria are able to have a symbiotic relationship with plants of the legume family and can thereby fix atmospheric nitrogen into available

[8] Allelopathy is a biological phenomenon by which an organism produces one or more biochemical that influence the germination, growth, survival, and reproduction of other organisms. ... Allelo-chemicals with negative allelopathic effects are an important part of plant defense against herbivory.

[9] *Rhizobium* are present in the soil in two different forms: if the host plant exists in the soil, they establish a symbiotic association with their host plant and fix the atmospheric nitrogen, and if not, they act as free-living saprophytic heterotrophs.

nitrogen for plants uptake; as a result, nitrogen (as an essential element for soil fertility and plant growth) is added to the soil.

Pursuing biodiversity on farm: Intercropping, an ecological engineering and climate smart way of building farm resilience, optimization of farm resources, increasing productivity, complementing income and minimizing risks

Principles for successful intercropping	
The associating crop should be complementary to the main crop.	Erect growing crops should be intercropped with cover crops.
The subsidiary crop should be of shorter duration and of faster growing habits, to utilize early the slow growing period of main crop.	Erosion permitting crops should be intercropped with erosion resisting crops.
The component crops should require similar agronomic practices.	The component crops should have different rooting patterns and depth of rooting.

Source: Chandrasekaran *et al.,* 2010

Site-specific intercropping and mixed cropping schemes should be devised and implemented in close consultation with DoA agriculture extension experts according to the local cropping sequences and patterns, but keeping in view the farm management practices, market demand, soil fertility, local soil characteristics, water availability, insect pests, diseases, weeds infestations and access to quality farm inputs.

CHAPTER 4 – CROP PRODUCTION TECHNOLOGY

4.1. Irrigation and water management

Water is a key input for sustainable rice production, therefore efficient and judicious water use is of paramount importance. Rice production is facing issues in view of shrinking water resources due to climate change and rapid industrial development. The need of growing more rice with less water is becoming unprecedented for food security. A number of water-saving techniques can help in conserving water resources while simultaneously producing rice with increased water use efficiency and reduced water losses. One of such techniques is the alternate wetting and drying (AWD) irrigation water management method in which water is applied to irrigate rice the field depending on climatic factors, soil and weather conditions until the soil surface cracks. AWD can save water by 25 to 30 percent compared to continuous flooding (DAR, 2019).

Continuous ponding also conserves water if water losses are effectively prevented. Ponding helps in controlling weeds, reduce plant stress and yield losses, improve nitrogen and phosphorus use efficiencies, and, in hot regions, protecting the crop from fluctuating temperature. The amount of water needed for ponding depends on soil type and rooting depth of rice. However, whichever method of water management is used, irrigation of crops is important at critical growth stages or moisture sensitive periods; if correct watering conditions are not met, a drastic yield reduction and impaired crop quality will be observed.

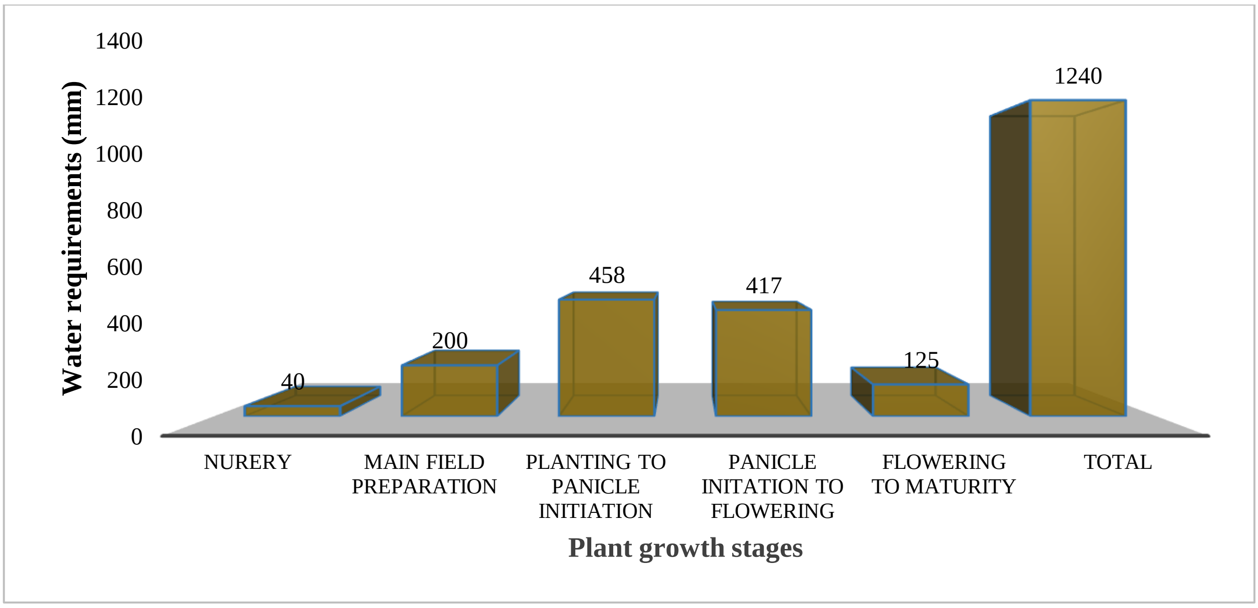
It should be noted that during the critical stages, irrigation intervals should not exceed the stipulated time, as this would lead to depletion of moisture below the saturation level. Paddy rice field water level should keep around three cm with gradual increased up to five to 10 cm as the plant progresses in growth. The water level should be maintained as such until the field is drained, seven to 10 days before harvest. Maintaining five cm water at all times from beginning to end of the flowering stage is the best option (Kumari *et al.*, 2021).

Below are the critical growth stages in rice growth cycle during which the crop must be irrigated depending on rice production system, soil and climatic conditions.

Figure 94. Critical stages for irrigation of rice crop

Source: Elaborated by the author

Figure 95. Stage wise water requirement of paddy crop



Source:

Kumar K. P., Barik D. K. 2015. Comparison of Agricultural Yield with and Without A Canal Head Regulator. International Journal of Advanced Technology in Engineering and Science, 3(9), 19–30.

ICRISAT. 2019. Pyawt Yaw Pump Irrigation Project Irrigation and Nutrient Management of major crops in PYPIP. Technical Bulletin. Technical Report. ICRISAT.

An efficient irrigation system should be used to minimize wastage of water and the risk of environmental harm on and off-site.

Water quality should be tested for health and systematically utilized. The water flowing down from livestock farms, hospitals, industries, wastewater, and any sources that may cause environmental harm are not used for irrigation purposes. The irrigation, fertilization and water management of the crop should be recorded as per Annex 3. Form-1, Irrigation and Source of Irrigation Water (1 to 3). Form-2, Irrigation (1 to 2)

Irrigation and water management: Refer to Annex 1 practice 1.2, 1.6.4 of Myanmar GAP guidelines Annex 2.1 practice 2.1.4 Annex 2.2 practice 2.2.4 and Annex 2.3 practice 2.3.5 for further guidance

Significant amounts of water are wasted due to faulty water management practices during rice production. To conserve the scarce resource of water and increase its use efficiency, the following practices should be adopted:

- Intensive land puddling reduces water losses through percolation and seepage.
- Application of FYM, compost or green manures reduce water losses through evaporation, percolation and seepage. Evaporation can only be reduced by 50 percent if the field is leveled.
- Conservation of rainwater through rainwater harvesting can significantly minimize surface runoff during wet season. The water harvested is not only used for rice production, but efficient ponding might also mitigate or prevent soil erosion and loss of the fertile top layer.

The water flowing down from livestock farms, hospitals, industries, waste water and any sources that may cause environmental harm are not used for irrigation purposes. (If the treated sewage water is used, it needs to comply with WHO Guidelines). The water quality used for irrigation, fertilizer and pesticide or fungicide application should be tested to assess the risk of chemical and biological contamination. If hazardous substances are detected, it should be recorded. The irrigation water potentially contaminated with microbes should be appropriately tested, as necessary, depending on its volume and the result be kept on record. If test results indicate it is contaminated with chemical and biological hazards, harmful to human health, safe water from any other sources should be used for irrigation. Alternatively, the appropriate water treatment should be applied, and a record of the water used should be kept. Wastewater from industries is not used due to risks to food safety. (If treated wastewater is used, it should comply with rules and regulations related to water quality.)

Irrigation water is essential for rice cultivation and may affect rice yield. Full irrigation is not necessary for young plants where small irrigation is recommended. If the rice field is dry during tillering stage (20 to 30 days or 30 days after transplanting), it may increase weed development; irrigation of two to four inches deep might therefore be recommended. Drainage is done at 20 days after flowering and seven to 10 days before harvesting, to ensure timely maturity of the crop. (Myanmar GAP guidelines, 2018).

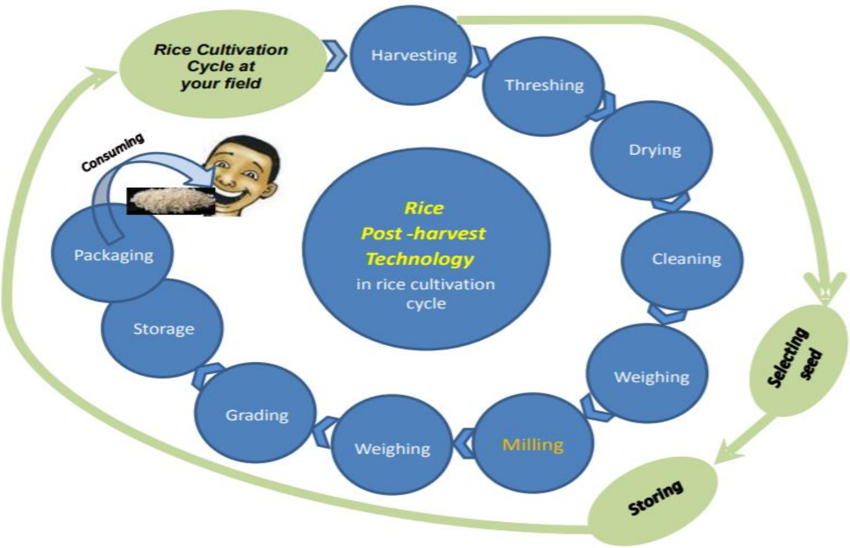
CHAPTER 5 – POST-HARVEST MANAGEMENT

5.1 Harvesting, produce handling and post-harvest management

5.1.1. Harvesting and produce handling

Post-harvest handing of rice is a combination of successive operations to the economic part of rice (grain) harvested from the field to transform it into a form, condition, or composition, adding value to the produce and prolong the shelf life as well as increasing its market value (Rice Post-harvest techniques, JICA 2015).

Figure 96. Different stage of rice post-harvest techniques and handling stages



Source: JICA. 2015. Rice Post-harvest techniques.

Rice harvesting is an important operation determining the quantity and quality of produce. Appropriately harvested crops can contribute to reduction of post-harvest losses, which are estimated at 25 to 40 percent in developing countries. Post-harvest losses are attributed to a multitude of factors, such as low socioeconomic status of rice farmers, low level of awareness and facilities for efficient post-harvest management, and less adoption of improved methods of production, harvesting, milling and storage. Weather forecasting and adjustment of harvesting management, i.e. method and time of harvesting is of immense importance. Rice production in proper moisture conditions and nutrient availability, harvesting fully matured grains at moisture levels below 26 percent and subsequent mechanical drying up to 15 percent moisture level, milling through pneumatic rubber rolls, storage under controlled environmental conditions, and integrated insect and pest management programs are the factors that can reduce quantitative and qualitative losses in rice crop (Bell *et al.*, 2000).

Rice harvesting varies with ecology, size of the fields, type of variety, local cultural practices, climate conditions, labour availability, access to market, market demand, and the intended purpose of straw use. Varieties prone to lodging, i.e. long statured and with tender stems, should be harvested manually to minimize the loss of quality and quantity of grain. Environmental conditions, such as high humidity and expectations of rains, favors manual harvesting. Harvesting operations can be done manually or through machines such as harvesting with reapers, rice threshers and combined harvesting, depending on the nature of the field and variety, farm size and local practices.

5.1.1.1. Harvesting

Harvesting involves the separation of grains from the plant to recover the mature grains and encompasses stalk cutting, stacking, handling and threshing. Harvesting at the right time and with the proper method are linked with qualitative characteristics of varieties. Mechanical harvesting is highly important for good grain quality and yield to avoid losses due to lodging, overdrying resulting in shattering losses, rodent and bird damage to the crop (Van den Berg *et al.*, 2007). Rice crop should be harvested when the panicles turn yellow and the grain moisture contents comes down to 20 to 26 percent, at which 80 percent of grain can be recovered from the panicles (Almera, 1997). A delay harvesting of 10 to 14 days will result in decreasing not only grain yield but also quality (DAR, 2019).

Harvesting stage is normally reached 25 to 35 days after flowering, by when about 75 percent of spikelets turn yellow, the grain is filled and tight, and grain color changes from green, to olive green, to yellow.

The following key considerations should be followed before and during rice harvesting:

- Farm implements used at harvesting time, packaging materials and harvesting methods may cause contamination that can affect rice quality.
- In case of mechanical harvesting, water from the field should be drained out seven to 10 days before harvesting to ensure uniform maturity and efficient harvesting operations.
- Date, method of harvesting and name of the rice variety harvested should be recorded for recall purposes.
- The harvesting and threshing machines should be thoroughly checked for other varieties' seeds, weeds and other crop varieties' seeds which may lower the quality of rice.
- The workers, animals, tractors, buildings and threshing areas are also checked before use for cleanliness, other varieties and other materials. After harvesting, less than five percent of other varieties and two percent of red seeds are acceptable in threshing areas (Myanmar GAP guidelines, 2018).
- Crops should be harvested at optimum stage of maturity, otherwise the grain moisture may drop below 18 percent. At this stage, when the crop is wet by rainfall or dewfall, the grain will absorb moisture and may germinate before threshing, deteriorating the grain quality. Some varieties are sensitive to shattering losses, especially in the event of delayed harvesting.
- In case of manual harvesting using a sickle, the straw should be cut four to five cm from the ground level. Bigger portions of straw should not be left in the field during harvesting as the stump may harbor stem borer or adult worms, hampering the completion of its life cycle. Ensure the uprooting of both straw and stumps, and fully incorporate them in the soil for the next crops to benefit.

Harvesting, threshing and drying: Refer to Annex 1 practice 1.8 of Myanmar GAP guidelines 2018, Annex 2.1 practice 2.1.6 Annex 2.2 practice 2.2.6 and Annex 2.3 practice 2.3.7 of ASEAN GAP guidelines for further guidance.	Time and method of crop harvesting should be recorded as per Annex 3 (Form.2. Harvesting and Handling Produce; 1 to 6).

5.1.1.2. Threshing

Threshing is an important post-harvest operation determining the quality and quantity of rice grain and consists of the separation of grains from rice straw and panicles. Various methods can be used for threshing rice, i.e. manual through hand, crushing with foot or by simply swinging, beating, and whipping actions against cleaned framed objects. Once threshed, grain will have many chaffs, foreign materials, therefore appropriate cleaning after drying should be carried out to remove all the underside materials present.

The following practices should be followed for efficient threshing:

- **Thresh the crop on the same day** of harvest if the rice straw are not wet from overnight rain or heavy dewfall. In such cases, the crop should be **field dried before threshing**. If the crop is harvested in the late morning, afternoon or half of the day, the crop should be threshed;
- To reduce grain losses due to beating effects, a **wider canvass with raised edges** should be used;
- The paddy should be **dried soon after threshing** in both the outdoor and indoor sheds, which are clean from any physical or chemical contamination. Always spread the grain for maximum exposure for drying. Avoid making heaps of grains to prevent grain fermentation due to moisture presence.

5.1.1.3. Drying

Appropriate drying is key to the produce quality in terms of taste, aroma, nutrition value and long shelf life. Rice is dried to reduce the moisture for proper milling and safe storage. The following key practices and methods should be followed for effective drying:

- The harvested paddy should be systematically dried during 24 hours after harvesting. If not, it will be easily broken and will reduce in milling percentage and grain quality. Less than 15 percent of seed moisture for sale and 13 percent of seed moisture for storage are acceptable (Myanmar GAP Guidelines, 2018).
- Once harvesting is done, the paddy is placed outside for sun drying on clean tarpaulin sheets or plastic sheets. The paddy is not dried in direct contact with concrete floors to avoid the contamination of other materials and potential for broken seeds (Myanmar GAP Guidelines, 2018).
- Ensure that the spread grain is turned over at regular intervals (every 30 minutes) using rakes for uniform drying.
- Slow drying with moderate temperature is good for preventing cracking as quick drying results in broken grains during milling.
- Rice grain should preferably be dried in a sheltered area, i.e. sheltered from direct sunlight or heat, also to shelter it from rain or moisty winds.
- The surface temperature should not go above 36℃ or must be kept lower. High temperature can also damage the seed embryo, which in turn decreases seed viability in case of using the grain as seed.
- When storing rice grain with high moisture contents, the mouth of the bags should open for air movement and release of heat and dampness.
- For drying of milling rice, about (200 to 400) baskets of paddy can be dried up to 15 percent of seed moisture content at 40 to 50ºC within eight to 10 hours. After drying, the produce is piled to keep cool (Myanmar GAP Guidelines, 2018).

Figure 97. Rice paddy evenly spread on a canvass for sun-drying

Figure 98. Using finger to measure depth of rice paddy spread on canvass

Figure 99. Rice paddy being stored away in poly-bags with the bag mouth left open to allow air movement

5.1.1.4. Cleaning

Cleaning is an important post-harvest operation determining the grade and quality of the product. Removal of materials such as rice straw chaff, foreign matters, immature and empty grain is important. Other matters, which degrade the quality of rice and create problems during the milling process are soil pieces, sand, small stones, metal debris, plastic pieces, paper pieces, twigs, remnants of branches, weed seeds, other grains and miscellaneous chemical and poisonous matters. The foreign materials not only degrade the quality, but also increase the cost of produce management, especially transporting and bagging, besides the wear-and-tear of grains:

To ensure effective cleaning of rice grains before milling the following tips should be followed:

- Remove all foreign matter, including broken grain, immature grain and shriveled grains for attaining high milling recovery.
- It is estimated mechanical efficiency and energy consumption of milling will increase by five percent, if percentage of foreign matter is less than one (JICA, 2015).
- Winnowing trays or sieves should be used and mechanical cleaners for efficient cleaning.
- Small stones that cannot be removed by winnowing, should be picked by hand.

SAFE MILLING OF RICE

- *Never feed the immature and empty grains into the milling machine as broken rice prompts breaking of other (immature) grains.*
- *Broken and immature rice cause unnecessary milling pressure to whole grains, causing more broken grains and immature grains to enter into the space between the whole grains.*
- *In case of polishing rice, it creates additional work for the milling unit to polish the surface area of broken rice grains, especially its cross-sectional area, resulting in more mechanical load on the milling unit during operation.*

5.1.1.5. Milling of rice

Rice milling is an important post-harvest management stage. The outer skin, hull and bran is removed mechanically to obtain the white kernel and endosperm of the grain for direct human consumption. Some byproducts are obtained, such as germ and brans, after milling; they can be used in livestock, poultry and aquaculture feed formulations. Ensure that clean, dried, and pure grain is fed to the milling machine to achieve the following qualitative and quantitative parameters:

- High milling recovery, if foreign matter, broken and immature grains are removed before milling.
- The post-harvest losses can be reduced if clean, dried and pure grain is fed to the machine, besides avoiding damages to grain and milling machines, as well as fuel/energy consumption.

5.1.1.6. Grading

Grading is the process of sorting milled rice into different grades on the basis visual observation and moisture content. Milled rice appears as whole grains, broken grains, off-types (grain of other varieties), colored grains and unmilled rice. Milled rice is graded based on different parameters such as moisture content, head rice and broken grains percentage, defectives, impurities, foreign matters, unmilled paddy, immature grains, and broken grains. If the moisture content of milled rice is high, there is risk of mold development and grain losses.

Figure 100. Package milled rice

5.1.1.7. Storage

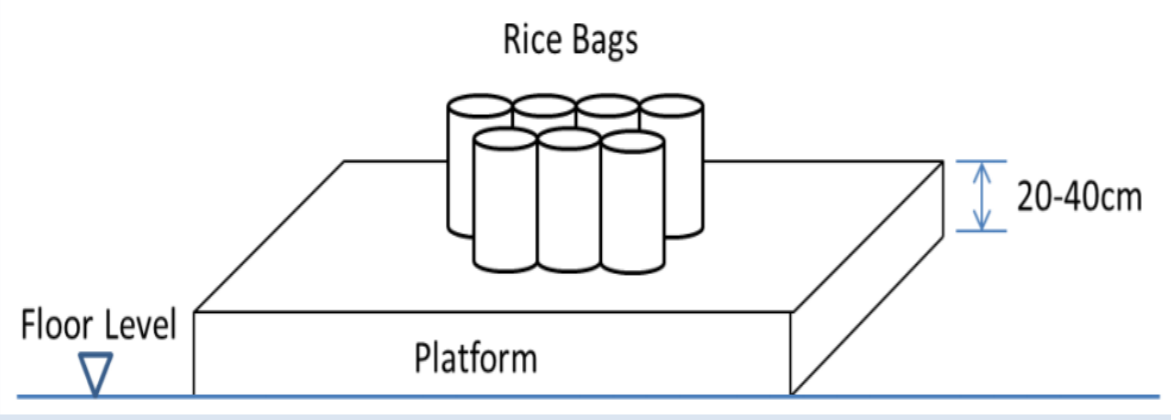
Appropriate storage is important to prevent losses caused by biotic and abiotic factors. The grain moisture content should be no more than 14 percent of its weight. The bags of grains should not be put directly on the floor, but on a rack 20 cm above the floor (JICA, 2015). If rice is meant for long-term storage, the grain moisture should be lower as high grain moisture content increases the chances of mold development, rapid loss of viability and reduction in eating and cooking quality. If the grain moisture is high, the bags' mouths should be kept open to release vapor and prevent internal heat from developing. Grains with high moisture contents should be further dried up to the desired level before storage.

Other useful practices for safe storage are described below;

- Produce should not be stored in the containers previously used for chemicals and other dangerous substances and materials.
- For export purposes, the prevention measures for storage pests/disease are practiced during the storage period to meet the requirements of the different exporting countries.
- Transport vehicles should be checked before use for cleanliness, availability of proper tarpaulins to cover the cargo, foreign objects and other materials, chemical contamination and pest infestation, and must also checked to ascertain dryness and the lack of moisture.
- Produce is stored and transported in areas separated from materials and goods that are a potential source of chemical, biological and physical contamination.
- All facilities where rice is stored in bulk need to have a detailed sanitation plan and designated persons be trained in maintaining the hygiene and safety of the premises and the produce stored therein.
- All good management practices must be documented, and workforce must understand to comply and adopt the guidelines.
- In order to ensure safe storage, the storage building should be rodent proof and in case there is risk of rodent infestation, take preventive/protective measures, such as closing all the holders at the doors roof, etc., where pests can enter, and also repair cracks in walls where pests can hide.

- The infested residue, which can contaminate the newly introduced produce in the store, should be removed.
- In order to maximize the use of space, ensure hygienic conditions and facilitate effective management, bags should be put in stacks.
- Sanitation of the storage place is highly important and can be attained by not mixing the old grain with new grain. Old, infested materials should either be removed or thoroughly fumigated. The storage structure, including machinery, packing bags and baskets, should be disinfected with fumigants or exposed to sun heat. Hermetic storage is also an effective way of safe storage as the airtight conditions cause reduced oxygen supply and increase carbon dioxide, reducing the chances of insects' infestation and mold development. Some special plants acting as natural fumigants can also be used.
- The stores should be well ventilated to prevent water condensation or dampness. The filled bags should be disinfected through exposure to sun for one to two days to destroy any remnants of insect pests (eggs, larvae). Bags' stacking should not more than 10 bags per stage, keeping inter-stage space for air circulation.
- Pellets should be used for each stack and regular turning over of the stacks performed to avoid buildup of moisture and fungus in the underneath bags. Storage at locations with a temperature of more than 300^{0}C should be avoided. As organic practices, the leaves of Neem (*Azadirachta indica*) can be used in the stores to avoid stored grain pests and insects.

Figure 101. Diagram showing improved method of rice grain storage



Source: Department of Agriculture & Livestock (NDAL) and Japan International Cooperation Agency (JICA). 2015. Handbook on rice post-harvest techniques. https://www.jica.go.jp/png/english/activities/c8h0vm00008t2xqj-att/activity10_04.pdf

Other improved practices for safe storage of rice are important to know and practice (Myanmar GAP guidelines, 2018) are given below:

- Implements and other packaging materials used for transportation and storage should be placed in separate areas to prevent any contamination, mixing of other variety seeds.
- The storage building should be properly structured with good ventilation and should be kept clean.
- Different rice varieties should be stored separately, appropriately labelled with name of the variety, quality/grade, date of storage and quantity.
- A clear record should be kept of quality and type of packaging materials and handling system for cleanliness.

It is crucially important, especially for rice produced for export, that the pesticide maximum residue limits and standards (Codex standards) of countries of export are complied with.

Storage handling and transportation: Refer to Annex 1 practice 1.5, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12 and 1.15 of Myanmar GAP Guidelines and Annex 2.1 practice 2.1.5, 2.1.6, 2.1.7, 2.1.9 Annex 2.2 practice 2.2.5, 2.2.6, 2.2.7, 2.2.8, 2.2.9, 2.2.10, 2.2.11 and 2.2.13, Annex 2.3 practice 2.3.6, 2.3.7, Annex 2.4 practice 2.4.1, 2.4.2, 2.4.3, 2.4.4 for further guidance.

Details of storage and transport conditions should be recorded as per Annex 3 (Form 1. Postharvest Practices; 1 to 3, Form 2. Storage and Transport; 1 to 3

CHAPTER 6 – OTHER GAP AND QUALITY ASSURANCE STANDARDS

6.1 Other gap and quality assurance standards

6.1.1. Produce quality production plan

In order to produce quality food, a quality production plan should be developed, implemented and kept on record. Quality plans should encompass practices that are critical to managing produce quality during production, harvesting and post-harvest handling, expected losses, causes, control measure, monitoring activities. Proper record of all the crop management practices should complement the quality plan (ASEAN GAP-produce quality module).

6.1.2. Building and structure

- Building and structure are constructed in separate places from farm animals, animal feed and compost-making venues. The floor of the building is checked before use for cleanliness, foreign objects, chemical contamination, pest infestation and other materials. The bamboo/timber are placed on the floor of the building with the intent of not being in direct contact with the floor.
- The building is structured and managed to have good ventilation and prevention of birds, rats and pest. Produce is not stored in direct contact with fuels, pesticides, fertilizers, including farm implements and other materials (Myanmar GAP Guidelines, 2018).
- The construction of buildings for cultivation, harvesting, drying, storage, milling and packaging is necessary. The building is structured and managed to minimize any potential source of produce contamination.
- Fuels and farm implements are placed in the separated areas where produce is packed and stored to minimize the risk of contamination.
- The buildings and structures for cesspits, sewage and drainage canals are constructed in the areas separated from drinking water supply and rice processing, to minimize contamination risks.
- The bulbs used in handling and packaging areas are covered and used to avoid the risk of contamination with the broken pieces of bulbs and other dangerous materials (Myanmar GAP Guidelines, 2018).

6.1.3. Animals and pest control

Farm animals and pets are excluded from the production site, particularly in areas where produce is harvested, packed, milled, and stored. Prevention and control measures are put in place to ensure insect pests are excluded from the production site, particularly in the areas where the produce is handled, packed and stored. The produce, packaging materials, other goods, traps, rodenticides and stimulating foods are stored in targeted places to minimize the risk of contamination (Myanmar GAP Guidelines, 2018).

6.1.4. Agrochemicals and other chemicals

Only registered products are purchased from licensed suppliers and used for crop production. Banned pesticides are not used. In the case of rice production for export purposes, the banned pesticides by the importing countries are not used. Integrated Pest Management should be practiced minimizing the pesticide use. Use of physical and biological control measures is better than using pesticides, fungicides and herbicides to minimize the risks of contaminating the environment (Myanmar GAP Guidelines, 2018).

Why Pre-harvest interval (PHI) is important: To comply with GAP standards for attaining food safety, the use of agrochemicals should be appropriately recorded with details, such as type of agrochemical used, method and time of application, and more importantly, details of PHI, i.e. number of days before the harvest during which application of pesticides is not allowed, so as to avoid the risk of any residual effects in the produce).

The chemicals obtained, stored, used, and the application and disposal of chemicals, are systematically handled and recorded as per Annex 3 (Form.1. Pesticides/Fungicides Application; 1to 4 and Form.2. Agro-Chemicals and Other Chemicals; 1 to 12).

6.1.5. Agriculture and other related materials

Equipment, materials and storage containers that come in contact with produce are cleaned to avoid contamination. Waste, chemicals, dangerous substances and other hazardous materials are not used for storage or for holding produce (Myanmar GAP guidelines, 2018).

6.1.6. Traceability and recall

- The compilation and steadiness of recording are necessary for traceability. Detailed actions taken are timely recorded with the signature of a person in charge. The records for each plot, season and crop are separately compiled and kept for further development.
- All practices taken and relevant data related to crop production, as well as significant evidence, are recorded for a minimum period of at least three years.
- The following is recorded: Pesticide application, source of rice seed, land preparation and rouging, monitoring of pest occurrence and control measures, and fertilizer application; harvesting, threshing and drying, packaging, storage, detailed list of tools used, and locations where the tools are placed and stored; results of lab tests, including soil, water and others, production costs, net profit/acre; and, labels recording the number of products, area and date of harvesting are tied on onto the tools and vehicles in the warehouse (Myanmar GAP Guidelines, 2018).

6.1.7. Documents and records

- All practices are reviewed at least once a year to ensure they are properly applied. Actions are taken to resolve the complaints related to produce quality. A record is kept of complaints and actions taken.
- The followings is recorded: Seed source, source of irrigation water, land preparation, rouging, survey record for pest and disease occurrence and control measures, application of pesticides, harvesting and threshing methods, drying methods to reduce seed moisture content, packaging and storage, source of produce, transportation and storage process, and all other actions taken (Myanmar GAP Guidelines, 2018).

6.1.8. Training and awareness

GAP-practicing farmers and their workers are trained to have relevant background knowledge in their area of responsibility. They should be provided the trainings on four GAP modules, namely:

- food safety;
- environmental management;
- produce quality; and
- workers health, safety and welfare; a record is kept of training attendance (Myanmar GAP Guidelines, 2018).

6.1.9. Review of practices

All practices are reviewed at least once a year to ensure they are properly applied. Actions are taken to resolve the complaints related to produce quality, and a record is kept of the complaint and actions taken (Myanmar GAP Guidelines, 2018).

6.1.10. Personal hygiene and worker welfare

- Personal hygiene is of immense importance for food safety and workers' health. Key instructions and guidance should be displayed at prominent locations on and off the farm and should be reinforced for compliance.
- Visible and potential sources jeopardizing hygiene of workers and produce, such as sewage, should be identified and remedial measures taken should be recorded.
- Regular demonstrations and role-plays should be practiced for implementation of personal hygiene practices. Appropriate hygiene facilities should be provided at the bathrooms and handwashing places as well as cleaning of equipment.
- Employers should provide some medicines for the workers. For emergency cases, employers need to inform to the Health Department. For personal hygiene and workers' welfare, basic needs, including restrooms should be accordingly provided.
- Minimum age for a worker is specified according to the regulations of the State. If there is no specification for minimum age, it must be over 18 years.
- The trainings related to personal hygiene practices, safely handling of vehicles and machines are provided to the newly-recruited workers.
- Medical check-up for foreigner workers is necessary and record is kept (Myanmar GAP Guidelines, 2018).

6.1.11. Cleaning and sanitation plan

A plan to prevent or minimize the risk of food contamination through the application of approved standards should be maintained. Packing, handling and storage areas and equipment, tools, containers, and materials that may be a source of contamination for the produce are identified, and instructions are prepared and followed for cleaning and sanitation. Moreover, appropriate cleaning and sanitation chemicals need to be selected to minimize the risk of these chemicals causing contamination of produce.

6.1.12. Conservation of biodiversity

To conserve and protect the local biodiversity and ensure resource sustainability of the local ecosystem, local legislation and regulations should be followed. Production and processing activities should not damage the environmental quality, thanks to the application of safe, efficient, and approved management of farm operations. Employers and workers should have appropriate knowledge and training in their area of responsibility relevant to good agricultural practices for environmental management. Burning of crop residues and packaging materials has tremendous deleterious effects on the air quality; therefore, safe disposal of waste is highly important. A safe disposal plan should be available for any verification and compliance. Complaints and actions taken to resolve complaints related to environmental management should be documented and available for consultation.

Refer to part II as ICM handbook on integrated pest, disease and weed management for (rice/paddy)

References

Alam, M., Bell, R. W., Hasanuzzaman, M., Salahin, N., Rashid, M. H., Akter, N., Khatun, M. 2020. *Rice (Oryza sativa L.) establishment techniques and their implications for soil properties, global warming potential mitigation and crop yields*. *Agronomy*, *10*(6), 888.

Ali, A., Mahmood, I. A., Hussain, F., Salim, M. 2007. *Response of Rice to Soil and Foliar Application of K~ 2SO~ 4 Fertilizer*. Sarhad Journal of Agriculture, *23*(4), 847.

Almera. 1997. *Grain losses at different harvesting times based on crop maturity*. In Lantin, R. Rice postharvest operation. Available online at www.fao.org/inpho/index-e.htm.

Anjum, F.M., Pasha, I., Bugti M.A., Butt, M.S. 2007. *Mineral composition of different rice varieties and their milling fractions.* Pakistan Journal of Agricultural Sciences, 44, pp.332-336.

Aung, M., Myint, Z. Y., Thura, S., Hunter, G., Singh, U., Sanabria, J. 2017. *Comparison of Yield Response and Nutrient Use Efficiency between Urea Deep Placement Technology and Farmers' Practice of Surface Broadcasting Urea on Transplanted Lowland Rice in Myanmar.* Myanmar Soil Fertility and Fertilizer Management, 47.

Aye, T. M. 2014. *Field Handbook: 4R Nutrient Management of Rice in Myanmar.* International Plant Nutrition Institute, Southeast Asia Program (IPNI SEAP), 16 pp.

Bardenas, E. A. 1965. *Morphology and Varietal Characteristics of the Rice Plant, The (Vol. 4).* Int. Rice Res. Inst.

Baskar, M., Solaimalai, A., Sivakumar, C., Suresh, R. 2000. *Phosphorus management in rice: A review.* Agricultural Reviews, 21(3), 168–177.

Bejbaruah, R., Sharma, R. C., Banik, P. 2013. *Split application of vermicompost to rice (Oryza sativa L.): its effect on productivity, yield components, and N dynamics*. Organic agriculture, 3(2), 123–128.

Bell, M. A., Bakker, R. R., De Padua, D. B., Rickman, J. 2000. *Rice quality management–Principles and some lessons.* In Quality assurance in agricultural produce. ACIAR Proceedings (No. 100).

Chandrasekaran, B., K. Annadurai, E. Somasundaram. 2010. *A textbook of agronomy*. Newage International Publisher, New Delhi.835 p.

Chang, T. T. 1976. *The origin, evolution, cultivation, dissemination, and diversification of Asian and African rices*. Euphytica, 25(1), 425–441.

Chaudhry, F. M., Wallace, A. 1976. *Responses of earlirose rice to iron, zinc, and BPDS when grown on calcareous soil.* Communications in Soil Science and Plant Analysis, 7(1), 89–91.

Chauhan, B. S. 2013. *Management strategies for weedy rice in Asia*. Int. Rice Res. Inst.

Chettri, G. B., Ghimiray, M., Floyd, C. N. 2003. *Effects of farmyard manure, fertilizers, and green manuring in rice-wheat systems in Bhutan: results from a long-term experiment*. Experimental Agriculture, 39(2), 129–144. Concentrations across Hainan Black Pepper Advantage Region. *Chinese Journal of Tropical Crops*, **33**, 1174–1179.

DAR. 2018. *Released New Varieties*. Department of Agricultural Research, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar, 168 pp

DAR. 2019. *Research outcomes after 65 years of DAR's effort in Myanmar*. Department of Agricultural Research, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, 202 pp

Das, S. K. 2014. *Role of micronutrient in rice cultivation and management strategy in organic agriculture—A reappraisal*. Agricultural Sciences, 2014. de Candolle, A. P. (1825). *Mémoires sur la famille des Légumineuses*. A. Belin.

Davis, J. G., Whiting, D. 2000. *Choosing a soil amendment* (Doctoral dissertation, Colorado State University. Libraries).

Denning, G., Baroang, K., Sandar., T. M. 2013. *No . 2 Rice productivity improvement in Myanmar.*

DOA- Extension Division 2006a. *Varietal characteristics of rice, oilseed crops and pulses crops*. Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.

DOA-Extension Division. 2006b. *Production Technologies for Achieving Target Yields of Paddy, Maize, Groundnut, Sesame, Sunflower, Black gram, Green gram, and Pigeon pea.* Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.

DOA-Extension Division. 2020. *Yearly Reports of Crop Production, Internal Report.* Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.

DOA-Rice Division. 2016. *Pamphlet of Rice Production Technologies for Monsoon and Pre-monsoon Seasons.* Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.

DOA-Rice Division. *Pamphlet of Do and Don't for System of Rice Intensification Technology.* Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, Myanmar.

Duhan, B. S., & Singh, M. 2002. *Effect of green manuring and nitrogen on yield of and uptake of micronutrients by rice.* Journal of the Indian Society of Soil Science, 50(2), 178–180.

Fageria, N. K., Moreira, A., Coelho, A. M. 2011. *Yield and yield components of upland rice as influenced by nitrogen sources.* Journal of Plant nutrition, 34(3), 361–370.

FAO. 2019. *Handbook for Farmer Field School on Climate Smart Agriculture in in coastal/delta zone Myanmar*. Sustainable Cropland and Forest Management in Priority Agroecosystems of Myanmar Project (GCP/MYA/017/GFF), Nay Pyi Taw. https://www.fao.org/documents/card/en/c/ca3815en

Ginigaddara, G. S., Ranamukhaarachchi, S. L. 2011. *Study of age of seedlings at transplanting on growth dynamics and yield of rice under alternating flooding and suspension of irrigation of water management.* Recent Research in Science and Technology, 3(3).

GRiSP (Global Rice Science Partnership). 2013. *Rice almanac, 4th edn.* International Rice Research Institute, Los Baños, p. 283.

Guo, T., Chen, K., Dong, N. Q., Shi, C. L., Ye, W. W., Gao, J. P., Lin, H. X. 2018. *GRAIN SIZE AND NUMBER1 negatively regulates the OsMKKK10-OsMKK4-OsMPK6 cascade to coordinate the trade-off between grain number per panicle and grain size in rice.* The Plant Cell, 30(4), 871–888.

ICRISAT. 2019. *Pyawt Yaw Pump Irrigation Project Irrigation and Nutrient Management of major crops in PYPIP*. Technical Bulletin. Technical Report. ICRISAT.

IFDC. 2018. *Soil Fertility and Fertilizer Management Strategy for Myanmar*. International Fertilizer Development Center, Alabama, USA, 69 pp

JICA. 2015. *Handbook on Rice Post-Harvest Techniques.* Department of Agriculture and Japan International Cooperation Agency (JICA) Project on Promotion of Small Holder Rice Production in Papua New Guinea (Phase-2), 25 pp.

Kaur, T. 2020. *Vermicomposting: An effective Option for Recycling Organic Wastes.* In Organic Agriculture. IntechOpen

Khan, A., Jan, M. T., Marwat, K. B., Arif, M. 2009. *Organic and inorganic nitrogen treatments effects on plant and yield attributes of maize in a different tillage systems.* Pak. J. Bot, 41(1), 99-108.

Khan, H. R., Faiz, B., Islam, K. R., Rahman, S., Adachi, T. 1991. *Effect of gypsum and zinc on the growth and yield of rice grown under saline water stress in coastal saline soil.* International journal of tropical agriculture, *9*(3), 182-189.

Khush, G. S. 2000. *Taxonomy and origin of rice.* Aromatic rices, 5–13.

Kolar, J. S., Grewal, H. S., Singh, B. 1993. *Nitrogen substitution and higher productivity of a rice-wheat cropping system through green manuring.* Trop. Agric, 70(4), 301–304.

Kumar K. P., Barik D. K. 2015. *Comparison of Agricultural Yield with and Without A Canal Head Regulator.* International Journal of Advanced Technology in Engineering and Science, 3(9), 19–30.

Kumar, P., Sharma, M. K. (Eds.). 2013. *Nutrient deficiencies of field crops: guide to diagnosis and management*. CABI.

Kumar, S., Verma, S. K., Singh, T. K., Singh, S. 2009. *Effect of nitrogen and sulphur on growth, yield and nutrient uptake by Indian mustard (Brassica juncea) under rainfed condition.* Indian Journal of Agricultural Sciences, 79(8), 648.

Kumar, V., Ladha, J. K. 2011. *Direct seeding of rice: recent developments and future research needs.* Advances in agronomy, 111, 297–413.

Kumari, P., Kumari, R., Sharma, B. 2021. *WATER MANAGEMENT IN RICE FARMING*.

Ladha, J. K., Watanabe, I., Saono, S. 1988. *Nitrogen fixation by leguminous green manure and practices for its enhancement in tropical lowland rice.* Sustainable agriculture: green manure in rice farming, 165–183.

Lasmini, S. A., Nasir, B., Hayati, N., Edy, N. 2018. *Improvement of soil quality using bokashi composting and NPK fertilizer to increase shallot yield on dry land.* Australian Journal of Crop Science, 12(11), 1743–1749.

Lefroy, R. D., Chaitep, W., Blair, G. J. 1994. *Release of sulfur from rice residues under flooded and non-flooded soil conditions.* Australian Journal of Agricultural Research, 45(3), 657–667.

Li, S., Pu, S., Deng, F., Wang, L., Hu, H., Liao, S., Ren, W. 2019. *Influence of optimized nitrogen management on the quality of medium hybrid rice under different ecological conditions.* Zhongguo Shengtai Nongye Xuebao/Chinese Journal of Eco-Agriculture, 27(7), 1042–1052.

Manguiat, I. J., Guinto, D. F., Perez, A. S., Pintor, R. M. 1992. *Response of rainfed lowland rice to green manuring with Sesbania rostrata.* Tropical Agriculture, London, 69(1), 73–77.

Mar, M., Saing, T., Thein, T., Palis, R. K. 1992. *Sesbania green manure program for rice farming in Myanmar.* In Proceedings of the International Rice Research Conference (pp. 21–25).

Meelu, O. P., Morris, R. A., Furoc, R. E., Dizon, M. A. 1992. *Grain yield responses in rice to eight tropical green manures.* Trop. Agric, 69, 133–136.

Mikkelsen, R. L., Roberts, T. L. 2021. *Inputs: Potassium Sources for Agricultural Systems.* Improving Potassium Recommendations for Agricultural Crops, 47.

Mitin, A. 2009. *Documentation of selected adaptation strategies to climate change in rice cultivation.* East Asia rice working group, 8.

MOALI. 2019. *Myanmar Agriculture at a Glance.* Ministry of Agriculture, Livestock and Irrigation, Nay Pyi Taw, 209 pp.

Mousavi, S. R., Eskandari, H. 2011. *A general overview on intercropping and its advantages in sustainable agriculture.* Journal of Applied Environmental and Biological Sciences, 1(11), 482–486. http://www.textroad.com

MOALI. 2018. *Myanmar GAP Guideline*. Department of Agriculture. Ministry of Agriculture, Livestock and Irrigation: Nay Pyi Taw, Myanmar, 2018. https://www.moali.gov.mm/en

Myint, A. K., Yamakawa, T., Kajihara, Y., Zenmyo, T. 2010. *Application of different organic and mineral fertilizers on the growth, yield and nutrient accumulation of rice in a Japanese ordinary paddy field.* Science World Journal, 5(2).

Myint, C. C. 1993. *Nature farming research in Myanmar: Effect of organic amendments and EM on rice production.* Exchange, 2(2.2), 2–2.

Myint, S., Tun, S. 2003. Study on the Effect of Seed Rate and Nitrogen Fertilizer Rate.

Naing, T. A. A., Kingsbury, A. J., Buerkert, A., Finckh, M. R. 2008. *A survey of Myanmar rice production and constraints.* Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 109(2), 151–168.

Oka, H. I., Chang, W. T. 1960. *Survey of variations in photoperiodic response in wild Oryza species. Botanical Bulletin of Academia Sinica, Taipei, 1,* 1-14.

Pan, S. G., Huang, S. Q., Jing, Z., Wang, J. P., Cao, C. G., Cai, M. L. Tang, X. R. 2012. *Effects of N management on yield and N uptake of rice in central China.* Journal of Integrative Agriculture, 11(12), 1993–2000.

Pandey, S., Byerlee, D., Dawe, D., Dobermann, A., Mohanty, S., Rozelle, S., Hardy, B. 2010. *Rice in the global economy.* Los Banos, Phillipines: International Rice Research Institute.

Proximity Design. 2019. *When it rains, it pours: Challenges and Opportunities in Myanmar's Sesame Value Chain, Field Institute San Francisco, Tokyo, for Myanmar small holders by Proximity Design.* https://proximitydesigns.org/wp-content/uploads/When-It-Rains-It-Pours-.pdf, 251 pp

Ramiah, K. 1937. *Rice in Madras: A Popular Handbook*. Superintendent, Government Press.

Rao, A. N., Wani, S. P., Ramesha, M. S., Ladha, J. K. 2017. *Rice production systems.* In Rice Production Worldwide (pp. 185–205). Springer, Cham.

Ren, D., Li, Y., He, G., & Qian, Q. (2020). Multifloret spikelet improves rice yield. New *Phytologist*, *225*(6), 2301–2306.

National Bureau of Agricultural Commodity and Food Standards Ministry of Agriculture and Cooperatives. 2008. *Good agriculture practices for rice.* 50 Phaholyothin Road, Ladyao, Chatuchak, Bangkok 10900. Published in the Royal Gazette Vol. 125 Section 139 D, B.E.2551 www.acfs.go.th

University of Arkansas Cooperative Extension Service. 1990. *Rice Production Handbook.* University of Arkansas Cooperative Extension Service, University of Arkansas System. Little Rock, Arkasas.

Roschevicz, R. J. 1931. *A contribution to the knowledge of rice.* Bull. Appl. Bot. Genet. Plant Breed., 27, 1–133.

Satyanarayana, V., Vara Prasad, P. V., Murthy, V. R. K., Boote, K. J. 2002. *Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice.* Journal of plant nutrition, 25(10), 2081–2090.

Shrestha, R. P., Thinn, A. A., Qasim, S. 2019. *An Assessment of Soil Fertility Management Practices in Central Dry Zone of Myanmar.* Journal of Agriculture and Sustainability, 12(2).

Siavoshi, M., Nasiri, A., Laware, S. L. 2011. *Effect of organic fertilizer on growth and yield components in rice (Oryza sativa L.).* Journal of Agricultural science, 3(3), 217.

Development Planning and Research Associates. 1983. *Small scale irrigation system for Peace Corps Volunteers*. https://eric.ed.gov/?id=ED307464

Sudarsono, W. A., Melati, M., Aziz, S. A. 2014. *Growth and yield of organic rice with cow manure application in the first cropping season*. Agrivita, Journal of Agricultural Science, 36(1), 19–25.

Sulistiani, R., Mufriah, D. 2013. *Response of growth and production of rice varieties caused by application amendment straw Bokashi and specific location of fertilization in salin soil.* In Proceedings of The Annual International Conference, Syiah Kuala University-Life Sciences and Engineering Chapter (Vol. 3, No. 1).

Tahir, R. M. A., Afzal, M., Sarwar, G., Noorka, I. R. 2019. *Smart Nutrition Management of Rice Crop under Climate Change Environment.* In Protecting Rice Grains in the Post-Genomic Era. IntechOpen.

Thein, S. S. 2016. *Natural Hazards Induced Salt-affected Soils for Rice Production in Myanmar.* Paper Collection of Unknown Contemporary Issues for Sustainable Environmental and Rural Development in Myanmar: Highlighting Collabouration with Bangladesh, Bhutan and Japan, 27.

Thiyagarajan, T. M., Gujja, B. 2012. *Transforming Rice Production with SRI (System of Rice Intensification) Knowledge and Practice: Reducing Agriculture Foot Print and Ensuring Food Security*.

Van den Berg, M. M., Hengsdijk, H., Wolf, J., Van Ittersum, M. K., Guanghuo, W., & Roetter, R. P. 2007. *The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China.* Agricultural Systems, 94(3), 841–850.

Van Slyke, L. L. 1932. *Fertilizers and crop production.* Orange Judd Publ. *Co. Inc., New York.*

Whyte, R. O. 1972. *The gramineae, wild and cultivated, of monsoonal and equatorial Asia. I. Southeast Asia.* Asian Perspectives, 15(2), 127–151.

Win, K. 1990. *Myanmar's Experience in Rice Improvement*. IRRI Research Paper Series, 1(141).

Win, P. P., Kyi, P. P., Maung, Z. T. Z., Myint, Y. Y., Cabasan, M. T. N., De Waele, D. 2020. *Crop rotation sequencing to minimize yield losses of summer-irrigated lowland rice in Myanmar caused by the rice root-knot nematode Meloidogyne graminicola*. International Journal of Pest Management, 66(4), 319–331.

Zhu, Z., Wei, G., Li, J., Qian, Q. Yu, J. 2004. *Silicon Alleviates Salt Stress and Increases Antioxidant Enzymes Activity in Leaves of Salt-Stressed Cucumber (Cucumis sativus L.).* Plant Science, 167, 527–533. http://dx.doi.org/10.1016/j.plantsci.2004.04.020

Zin, W. Y. L., Teartisup, P., Kerdseub, P. 2019. *Evaluating traditional knowledge on climate change (TKCC): a case study in the Central Dry Zone of Myanmar.* Environment and Natural Resources Journal, 17(2), 1–29.

Zu, C., Wu, H.S., Tan, L.H., Yu, H., Yang, J.F., Li, Z.G. 2012. *Analysis of Correlation between Soil pH and Nutrient Concentrations across Hainan Black Pepper Advantage Region.* Chinese Journal of Tropical Crops, 33, 11741179.

Annexes

Annex 1. Myanmar GAP guidelines for rice

S.No	GAP parameters	Recommended GAP practices
1.1	**Site selection**	The site and its surrounding areas must not be contaminated with any chemical and biological hazards. The layout map of the site and a record are kept of the actions taken. Rice is grown in loam, silt loam and sandy loam and silty clay loam. It can be grown in both irrigated and rainfed areas if water is available. The optimum soil pH for rice growing is at 5.5–7.0. The site is monitored and managed for any potential contaminations.
1.2	**Water**	The water flowing down from livestock farms, hospitals, industries, waste water and any sources that may cause environmental harm are not used for irrigation purpose. (If the treated sewage water is used, it needs to comply with WHO Guideline). The water quality used for irrigation, fertilizer application, pesticide/fungicide application should be tested to assess the risk of chemical and biological contamination. If hazardous subsistence are there, it should be recorded. The water used for irrigation which is potential contamination with microbes should be tested at appropriate times as necessary depending on the volume of irrigation water. The result is recorded. If test result indicates that the water is contaminated with chemical and biological hazards that may cause harmfulness to the people's health, potential safe water from any other sources is used for irrigation. Alternatively, the appropriate water treatment is done, and the water is used for irrigation and a record is kept. Waste water from industries is not used for GAP crop production and value-added production. (If the treated waste water is used, rules and regulation related to water quality is complied.)
1.3	**Seed and seedling**	Good quality and local adaptable varieties that are free from pest and disease should be selected and used for production. The characteristics of quality seed are more than 80 percent of germination, 98 percent of seed purity and less than 0.5 percent of other varieties. Seed source should be from official registered/licensed places such as Central Seed Farms, Rice Research Centres or Seed Farms, Cooperative Farms, other recommended places by responsible organizations. Alternatively, the farmers can produce their own seeds in their own field separated from grain production areas or other selected fields where the characteristics of plant variety are uniform. Seeds produced in the field where rouging is done properly are used. A record is kept of seed sources.
1.4	**Fertilizers and soil additives**	The fertilizers and soil additives used are free from chemical and biological contaminations that may be harmful on and off the site. The natural fertilizers are used after making thoroughly compost. Areas or facilities for mixing and loading of fertilizers and soil additives, storage and for composting of organic matter are avoided. The registered products are only purchased from licensed suppliers and used for crop production. The application of fertilizers and soil additives are recorded. A record is kept of soil amendment practices taken for improving its properties. Application of pesticides or seed treatment for prevention of soil insects are avoided to minimize the harmfulness to the effective microbes. Summer ploughing is recommended for soil quality improvement.
1.5	**Agro-chemicals and other chemicals**	The registered products are only purchased from licensed suppliers and used for crop production. Banned pesticides are not used. For export-purpose rice production, the banned pesticides by the importing countries are not used. The Integrated Pest Management should be practiced minimizing the pesticide use. Use of physical and biological control measures is better than use of pesticide, fungicide and herbicide to minimize the risks of contaminating the environment.
1.6	**Care and management**	The following measures should be practiced for producing good quality rice; **(6.1) Sowing** Based on the different soil type, climate variation and water availability, local

adaptable varieties and appropriate agricultural practices should be applied.

Levelling of rice field could reduce the seed rate, if there is no rats, birds and weeds occurrences.

Row to row and plant to plant spacing of (8 × 8) inches or (9 × 6) inches will provide about (100,000–110,000) plants/acre.

Skip 1 row/6 rows for seed production and skip 1 row/10 rows for grain production.

When transplanting is done, correct seedling age and number of plants per hill is important for plant population density.

Nursery is prepared by Raised-Bed System. Transplant 2–3 seedlings of (20–25) days old at 1.5 inches of seed depth.

- Once up-rooted, transplanting is done to reduce the transplanting shock.
- Recommended seed rates are; 1 basket/acre for transplanting, 1.5 baskets/acre for wet seeding and 2 baskets/acre for dry seeding respectively.

(6-2) Rouging and Weed Control

- It is recommended not to exceed 0.50 percent of other variety and 0.02 percent of red seed.
- Rouging and weed control measures at appropriate times are recommended during the crop season.
- Regular monitoring of off-type inspection and rouging, if necessary, should be done at tillering stage, flowering time and ripening stage respectively.
- At tillering stage, any off-types which are different from the characteristics of target variety in terms of tillering type, leaf stature, leaf colour, stem colour, leaf size and plant height are checked and removed immediately during the tillering stage.
- At flowering time, any off-types which are different from the characteristics of target variety in terms of early/late flowering time, spikelet shape, colour of spikelet and male pollen are checked and removed immediately during the flowering time.
- Any off-types which are different from the characteristics of target variety in terms of type of spikelet are checked and removed immediately during the reproductive stage.
- Any off-types which are different from the characteristics of target variety in terms of seed size, seed colour and type of ripening during the ripening stage.

(6.3) Fertilizer Application

- It is recommended that fertilization application, if necessary, should be done based on plant performance/growth in fertile soils (alluvial soils).
- The following practices for GAP purpose production, if necessary, are recommended;
- Amount of fertilizer required is calculated based on the plot size and indigenous nutrient contents and is applied.
- Weed control should be done before fertilizer application, especially in the early vegetative stage.
- Irrigation water is checked before fertilizer application and maintained about 2 inches deep in the field. Regular irrigation is done (3–5) days after fertilizer application.
- Right ratio/amount of fertilizer at right time is applied based on different rice variety and different soil type.
- About 56 lbs/acre of compound fertilizer or 3 toones of natural fertilizer (compost of cow-dung) is applied as basal.
- About 56 lbs/acre of Urea and 3 bags/acre of compost are mixed and applied at sowing time.

(6.4) Irrigation/Drainage

- Irrigation water is essential for rice cultivation and irrigation may affect rice yield. Full irrigation is not necessary for young plants and small irrigation is recommended.
- If the rice field is dry during tillering stage (20–30 days or 30 days after transplanting), it may increase weed development. Therefore, irrigation of 2–4 inches

		deep is recommended to control weed development. - Drainage is done at (7–10) days before harvesting and (20) days after flowering to ensure same maturity. **(6.5) Pest and disease control** - Monitoring in accordance with the guidelines of pest and disease control measures is done and if necessary, control effectively by practicing appropriate control measures. - The IPM is practiced. Application of pesticides, fungicides and herbicides is necessary at Economic-Threshold Level. - Post-Harvest Intervals (PHIs) are observed and followed exactly. - For export-purpose production, use of banned chemicals by importing countries is avoided. The registered products are only purchased from licensed suppliers and used.
1.7	**Agriculture and other related materials**	Equipment, materials that contact produce and containers used for storage and other materials are cleaned not to contaminate the produce. Waste, chemicals, other dangerous subsistence and materials are clearly identified and are not used for storage and holding produce.
1.8	**Harvesting and threshing**	- Harvesting at right time may increase milling percentage. The proper harvesting times depending on different varieties are as follows; (a) (25–35) days after flowering time or about 85 percent of spikelet/ear matured (b) About 75 percent of spikelet turns yellow colour - Farm implements/tools used at harvesting time, packaging materials and harvesting methods may cause potential sources of contamination that can affect rice quality. Therefore, a proper harvesting time is planned and managed accordingly. A record is kept of practices and process taken. The followings are recommended when harvesting is done by machines. - Drainage (no water in the field) is done at (7–10) days before harvesting to ensure same maturity. - According to the previous use of threshing machine, the names of the varieties threshed by that machine are recorded. Machine is checked before use to make sure cleanliness, other varieties and other materials are not there. - The workers, animals, tractors, buildings and threshing areas are also checked before use for cleanliness, other varieties and other materials. After harvesting, less than 5 percent of other variety and 2 percent of red seed are acceptable in threshing areas.
	Drying	- Harvested produce should be systematically dried during 24 hours after harvesting. If not so, the produce will be easily broken, and it will reduce in milling percentage and grain/seed quality. Less than 15 percent of seed moisture for sale and 13 percent of seed moisture for storage are acceptable. - Once harvesting is done, the produce is placed outside for sun drying on cleaning tarpaulin sheets or plastic sheets. Produce is not dried in direct contact with concrete floors to avoid the contamination of other materials and potential for broken seeds. - Harvested produce is placed for sun drying on tarpaulin sheets in optimum thin layer (about 2 inches layer). Upper and lower layer produce are changed in reverse direction in each 2 hours for good drying. If the layer is rather thick or thin, it will reduce in milling quality. The produce is properly dried up to (12–14) percent of seed moisture content. - If paddy dryer is used, the dryer temperature should never exceed 50ºC at 60 percent RH. If the drying rate is too high, the produce will be easily broken. - For drying of milling rice, about (200–400) baskets of produce can be dried up to 15 percent of seed moisture content at 40–50ºC within 8-10 hour. After drying, the produce is piled to keep a cool.
1.9	**Storage, transport and**	- Farm implements and packaging materials used for transportation and storage are placed in cleaning areas to prevent any contamination, mixing with other variety, and quality deterioration. - The buildings or places used for collecting and storage of produce are structured and managed to have in good ventilation, cleanliness and prevention of birds, other

	packaging	animals, any contamination, mixing with other variety and dangerous materials. - If more than one variety is stored, it is important to avoid mixing of each variety in storage areas. Rice bags are properly placed and stored on (2–3) inches-high timber floor by piling up in a row and in a line systematically to have in a good ventilation, to maintain optimum seed moisture content. Labels recorded the name of the variety, date and amount of stored are hung in the warehouse. The packaging materials used for milled rice are checked and managed for cleanliness and safe for storage. A record is kept of quality and type of bags/packaging materials and handling system for cleanliness. - Farm implements and packaging materials used for transportation and storage are placed in cleaning areas to prevent mixing with other variety any contamination, dangerous materials that can cause harmfulness to the consumers.
1.10	**Building and structure**	- The construction of building for cultivation, harvesting, drying, storage, milling and packaging is necessary. The building is structured and managed to minimize any potential source of contaminating produce. - Fuels and farm implements are placed in the separated areas where produce is packed and stored to minimize the risk of contaminating produce. - The buildings and structures for cesspit, sewage and drainage canal are constructed in the areas separated from drinking water supply and rice processing areas to minimize the risk of contaminating produce. - The bulbs used in handling and packaging areas are covered and used to avoid the risk of contaminating produce with the broken pieces of bulbs and other dangerous materials.
1.11	**Animals and storage-pest control**	- Farm animals and pets are excluded from the production site particularly for the areas where produce is harvested, packed, milled and stored. - Prevention and control measures are managed/ prepared to prevent insect pests are excluded from the production site particularly for the areas where the produce is handled, packed and stored - The produce, packaging materials, other goods, the traps, rodenticides and stimulating foods are put/stored in targeted places to minimize the risk of contaminating produce.
1.12	**Documents and records**	- All practices are reviewed at least once each year to ensure all practices are properly done. Actions are taken to resolve the complaints related to produce quality. A record is kept of complaints and actions taken. The followings are recorded; - Seed source, source of irrigation water, land preparation, rouging, survey record for pest and disease occurrence and control measures, application of pesticides, harvesting and threshing methods, drying methods to reduce seed moisture content, packaging and storage, source of produce, transportation and storage process and all actions taken are recorded.
1.13	**Traceability and recall**	- The compilation and maintenance of recording are necessary for the traceability. Detailed actions taken are timely recorded with a signature of responsible person. The records for each plot, each season and each crop are separately compiled and kept for further development. - All practices taken, relevant data related to crop production and significant evidence are recorded for a minimum period of at least three years. The followings are recorded; - Pesticide application, source of rice seed, land preparation and rouging, monitoring of pest occurrence and control measures, fertilizer application, harvesting, threshing and recording, drying, packaging, storage, detailed list of implements/tools used and building and places where the implements are placed and stored, results of lab tests including soil, water and others, production cost, net profit/acre, - Labels recording the number of item/production area/date of harvesting are tied on the materials/goods/implements in the warehouse and vehicles.
1.14	**Trainings**	- GAP practicing farmers and their workers are trained to have background knowledge in their area of responsibilities relevant to Good Agricultural Practices. They should be provided the trainings about four GAP modules namely; Food Safety Module,

		Environmental Management Module, Produce Quality Module and Workers Health, Safety and Welfare Module. A record is kept of training attendance.
1.15	**Review of practices**	- All practices are reviewed at least once each year to ensure all practices are properly done. Actions are taken to resolve the complaints related to produce quality, and a record is kept of the complaint and actions taken.
1.16	**Personal hygiene and workers welfare**	- Written instructions on personal hygiene practices are also displayed in prominent locations and also distributed to them and encourage them to practice. The rest rooms and cleaning facilities are placed for easy access and maintained for cleanliness. Sewage is carefully disposed of in a manner that minimizes the risk of contamination of workers. - Employer provides some medicines for the workers. For emergency case, employer needs to inform to the Health Department. For personal hygiene and workers' welfare, basic needs including rest rooms should be accordingly provided. - Minimum age for a worker is specified according to the regulations of the State. If there is no specification for minimum age, it must be over 18 years. - The trainings related to personal hygiene practices, safely handling of vehicles and machines are provided to the newly recruited workers. - Medical check-up for foreigner workers is necessary and record is kept.

Annex 2: Relevant ASEAN guidelines

Annex 2.1. Module for produce quality–GAP requirements

S.No	GAP requirement	Objectives	Required practice (s)
2.1.1	**Quality production plan**	To manage produce quality[10]	1. Practices that are critical to managing produce quality during production, harvesting and postharvest handling are identified in a quality plan for the crop grown.
2.1.2	**Planting material (seed, variety, types)**	To improve quality and optimize market return	1. Crop varieties are selected to satisfy market requirements; 2. Good quality of planting materials is evidenced from certified sources
2.1.3	**Fertilizers and soil additives**	To ensure application of quality, safe, ecofriendly, sites specific, fertilizers and soil additives for improved produce quality	1. Nutrient application is based on recommendations from a competent authority or on soil or leaf or sap testing and the nutritional requirements for the crop grown. 2. Equipment used to apply fertilizers and soil additives is maintained in working condition and checked for effective operation at least annually by a technically competent person. 3. Areas and facilities for composting of organic materials are located, constructed and maintained to prevent contamination of crops by diseases. 4. The application of fertilizers and soil additives is recorded, detailing the name of the product or material, date, treatment location, application rate and method, and operator name.

[10] The quality plan encompasses steps in growing, harvesting and postharvest handling of the crop, expected losses in quality, causes and control measures, monitoring activities and record keeping to be practiced to prevent or minimize the risk of the hazard affecting the quality.

2.1.4	**Irrigation and water management**	To ensure efficient fulfillment of crop irrigation water requirement in a site and crop specific for increased yield, quality and water use efficiency	1. Irrigation use is based on crop water requirements, water availability, and soil moisture levels. 2. A record of irrigation use is kept, detailing the crop, date, location, and volume of water applied or duration of irrigation.
2.1.5	**Chemical (Agrochemicals)**	To prevent quality losses of the produce by using safe, approved and integrated methods of agrochemicals applications	1. Employers and workers have been trained to a level appropriate to their area of responsibility for chemical application. 2. Crop protection measures are appropriate for the control of pests. 3. Integrated pest management systems are used where possible. 4. Chemicals are only obtained from licensed suppliers. 5. Chemicals used on crops are approved by a competent authority in the country where the crop is grown and intended to be traded, and documentation is available to confirm approval. 6. Chemicals are applied according to label directions, or a permit issued by a competent authority. 7. A chemical rotation strategy and other crop protection measures are used to avoid pest resistance. 8. Equipment used to apply chemicals is maintained in working condition and checked for effective operation at least annually by a technically competent person 9. The application of chemicals is recorded for each crop, detailing the chemical used, reason for application, treatment location, date, rate and method of application, weather conditions, and operator name.
2.1.6	**Harvesting and handling produce**	To prevent and minimize quality loss through safe and efficient harvest and postharvest handling	1. An appropriate maturity index is used to determine when to harvest produce. 2. An appropriate technique is used for harvesting of produce. 3. Equipment and tools are suitable for harvesting and are checked for cleanliness before use and cleaned as required. 4. Containers are suitable for harvesting of produce and are not overfilled. 5. Liners are used to protect produce if containers have rough surfaces. 6. Containers are covered to reduce moisture loss and exposure to the sun. 7. Containers are checked for soundness and cleanliness before use and cleaned or discarded as required. 8. Produce is harvested in the coolest time of the day and harvesting in the rain is avoided if possible. 9. Produce is removed from the field as quickly as

			possible. 10. Harvested produce is placed in the shade if long delays occur before transport. 11. Packed containers are not stacked on top of each other unless they are designed to support the container and minimize mechanical damage. 12. Containers are secured during transport to minimize mechanical damage. 13. Equipment is constructed to minimize excessive drops and impacts. 14. Equipment, containers and materials that contact produce are regularly cleaned and maintained to minimize mechanical damage. 15. Measures are taken to prevent the presence of pests in and around handling, packing and storage areas. 16. Where required, produce is treated to minimize disease development and loss of quality. 17. Water used after harvest for handling, washing, and produce treatment is treated or changed regularly to minimize contamination from spoilage organism. 18. Produce is packed and stored in covered areas. 19. Produce is not placed in direct contact with soil or the floor of handling, packing or storage areas. 20. Produce is graded and packed according to customer or market requirements. 21. Protective materials are used where required to protect produce from rough surfaces of containers and excessive moisture loss. 22. Field heat is removed using appropriate cooling methods.
2.1.7	**Storage and transport**	To prevent or minimize quality loss through safe, product specific and approved storage and transportation of produce	1. For long delays before transport, produce is held at the lowest suitable temperature available 2. Transport vehicles are covered, and appropriate temperature conditions are used to minimize quality loss. 3. Transport vehicles are checked before use for cleanliness, foreign objects, and pest infestation, and cleaned if there is a significant risk of mechanical damage and contamination from spoilage organisms. 4. Mixing of non-compatible produce during transport is avoided. 5. Produce is transported quickly to the destination.

2.1.8	**Traceability and recall**	To implement an effective system[11] for identifying and tracing produce is needed to investigate causes of quality loss when it occurs and to prevent re-occurrence of the problem	1. Each separate production site is identified by a name or code. The name or code is placed on the site and recorded on a property map. The site name or code is recorded on all documents and records that refer to the site. 2. Packed containers are clearly marked with an identification to enable traceability of the produce to the farm or site where the produce is grown. 3. A record is kept of the date of supply, quantity of produce and destination for each consignment of produce.
2.1.9	**Employees and workers training**	To improve knowledge and skills of employees and workers for safe and approved handling of farm produce	1. Employers and workers have appropriate knowledge or are trained in their area of responsibility relevant to good agricultural practice and a record of training is kept.
2.1.10	**Documents and records**	To ensure effective record keeping for easy, evidence based and timely investigation of quality loss of the produce	1. Records of good agricultural practices are kept for a minimum period of at least two years or for a longer period if required by government legislation or customers. 2. Out of date documents are discarded and only current versions are used.
2.1.11	**Review of practices**	To confirm and reinforce the implementation of practices and improvement as necessary	1. All practices are reviewed at least once each year to ensure that they are done correctly, and actions are taken to correct any deficiencies identified. 2. Record is kept of practices reviewed and corrective actions taken. 3. Actions are taken to resolve complaints related to produce quality, and a record is kept of the complaint and actions taken.

Figure A2.1. Compost and crop residues should be stored away from production sites to avoid produce contamination)

Figure A2.2. Workers training through demonstration

[11] The production site be identified by a name or cod and each packed container is clearly marked with an identification code including record of the batch identification, date of supply, source, destination and records of farm operation.

Figure A2.3. Chemicals should be applied according to label directions or a permit issued by a competent authority.

Annex 2.2. Module for food safety–GAP requirements

S.No	GAP requirement	Objectives	Required practice (s)
2.2.1	**Site history and management**	To document and manage sites of productions for prevention/control of chemical, biological and physical contamination for improved food safety	1. The risk of contaminating produce with chemical and biological hazards from the previous use of the site or from adjoining sites is assessed for each crop grown and a record is kept of any significant risks identified. 2. Where a significant risk of chemical or biological contamination of produce has been identified, either the site is not used for production of fresh produce or remedial action is taken to manage the risk. 3. If remedial action is required to manage the risk, the actions are monitored to check that contamination of the produce does not occur and a record is kept of the actions taken and monitoring results. 4. The location of any contaminated sites on the property, which are unsuitable for production of fresh produce, is recorded.
2.2.2	**Planting material**	To prevent and minimize contamination by using safe and approved planting materials	1. If planting material is produced on the farm, a record is kept of any chemical treatment used and the reason for use. 2. If planting material is obtained from another farm or nursery, a record is kept of the name of the supplier and the date of supply. 3. Varieties known to be toxic for human consumption are not grown.
2.2.3	**Fertilizers and soil additives**	To prevent or minimize the risk of chemical and biological contamination through safe, appropriate and approved organic/inorganic fertilizers and soil additives for better food safety	1. The risk of chemical and biological contamination of produce from the use of fertilizers or soil additives is assessed for each crop grown and a record is kept of any significant hazards identified. 2. If a significant hazard from the use of fertilizers or soil additives is identified, measures are taken to minimize the risk of contamination of produce. 3. Fertilizers and soil additives are selected to minimize the risk of contamination of produce with `heavy metals. 4. Untreated organic materials are not applied in situations where there is a significant risk of contaminating the produce. 5. Where an organic material is treated on the farm before

			application, the method, date and duration of the treatment are recorded. 6. If a product containing organic materials is obtained from off the farm and there is a significant risk of contaminating the produce, documentation is available from the supplier to show that the material has been treated to minimize the risk of contaminating the produce. 7. Human sewage is not used for production of any fresh produce destined for human consumption. 8. Equipment used to apply fertilizers and soil additives is maintained in working condition and checked for effective operation at least annually by a technically competent person. 9. Areas or facilities for storage, mixing and loading of fertilizers and soil additives and for composting of organic materials are located, constructed and maintained to minimize the risk of contamination of production sites and water sources. 10. A record of fertilizers and soil additives obtained is kept, detailing the source, product name, and date and quantity obtained. 11. The application of fertilizers and soil additives is recorded, detailing the date, name of the product or material used, treatment location, application rate, application method, and operator name.
2.2.4	**Irrigation and water management**	To prevent or minimize the risk of chemical and biological food contamination during irrigation/fertigation or other water treatments through assessed, safe and documented water sources	1. The risk of chemical and biological contamination of produce is assessed for water used before harvest for irrigation, fertigation, and applying chemicals, and after harvest for handling, washing, produce treatment, and cleaning and sanitation. A record is kept of any significant hazards identified. 2. Where water testing is required to assess the risk of contamination, tests are conducted at a frequency appropriate to the conditions affecting the water supply, and a record of test results is kept. 3. Where the risk of chemical and biological contamination of produce is significant, either a safe alternative water source is used or the water is treated and monitored and a record is kept of the treatment method and monitoring results. 4. Untreated sewage water is not used during production and postharvest handling of produce. In countries where the use of treated water is permitted, the water quality must comply with the relevant regulations.
2.2.5	**Chemicals (Agrochemicals)**	To prevent or reduce the risk of chemical food contamination through the use of known, approved, and safe use of agrochemical for better food safety	1. Employers and workers have been trained to a level appropriate to their area of responsibility for chemical use. 2. If the choice of chemical products is made by advisers, proof of their technical competence is available. 3. Integrated pest management systems are used where possible to minimize the use of synthetic chemicals. 4. Chemicals and biopesticides used on crops are approved by a competent authority in the country where the crop is grown and intended to be traded, and documentation is available to confirm approval. 5. Up to date information on chemical MRL standards for

			the country where produce is intended to be traded is obtained from a competent authority. 6. Chemicals are applied according to label directions, or a permit issued by a competent authority. 7. To check that chemicals are applied correctly, produce is tested for chemical residues at a frequency required by customers or a competent authority in the country where produce is intended to be traded. The laboratory used is accredited by a competent authority. 8. The mixing of more than two chemicals is avoided, unless recommended by a competent authority. 9. Withholding periods for the interval between chemical application and harvest are observed. 10. Equipment used to apply chemicals is maintained in working condition and checked for effective operation at least annually by a technically competent person. 11. Equipment is washed after each use and washing waste is disposed of in a manner that does not present a risk of contaminating the produce. 12. Surplus application mixes are disposed of in a manner that does not present a risk of contaminating the produce. 13. Chemicals are stored in a well-lit, sound and secure structure, with only authorized people allowed access. The structure is located and constructed to minimize the risk of contaminating produce and equipped with emergency facilities in the event of a chemical spill. 14. Liquid formulations of chemicals are not stored on shelves above powders. 15. Chemicals are stored in the original container with a legible label and according to label directions or instructions from a competent authority. If a chemical is transferred to another container, the new container is clearly marked with the brand name, rate of use and withholding period. 16. Empty chemical containers are not re-used and are kept secure until disposal. 17. Empty chemical containers are disposed of according to relevant country regulations and in a manner that minimizes the risk of contaminating produce. Official collection and disposal systems are used where available. 18. Obsolete chemicals that are unusable or no longer approved are clearly identified and kept secure until disposal. 19. Obsolete chemicals are disposed of through official collection systems or in legal off-site areas. 20. The application of chemicals is recorded for each crop, detailing the chemical used, reason for application, treatment location, date, rate and method of application, withholding period, and operator name. 21. A record of chemicals obtained is kept, detailing chemical name, supplier of chemical, date and quantity obtained, and expiry or manufacture date. 22. Where applicable, a record of chemicals held in storage is kept, detailing chemical name, date and quantity obtained and date when completely used or disposed of. 23. If chemical residues in excess of the MRL are detected

			in the country where produce is traded, marketing of the produce is ceased. The cause of the contamination is investigated, corrective actions are taken to prevent re-occurrence, and a record is kept of the incident and actions taken. 24. Fuels, oils, and other non-agrochemicals are handled, stored and disposed of in a manner that minimizes the risk of contaminating produce.
2.2.6	**Harvesting and handling produce**	To prevent or reduce the risk of physical, chemical, biological contamination during postharvest handling	1. Equipment, containers and materials that contact produce are made of materials that will not contaminate produce. 2. Containers used for storage of waste, chemicals, and other dangerous substances are clearly identified and are not used for holding produce. 3. Equipment and containers are regularly maintained to minimize contamination of produce. 4. Equipment, containers and materials are stored in areas separated from chemicals, fertilizers and soil additives and measures are taken to minimize contamination from pests. 5. Equipment, containers and materials are checked for soundness and cleanliness before use and cleaned, repaired or discarded as required. 6. Harvested produce is not placed in direct contact with soil or the floor of handling, packing or storage areas.
2.2.7	**Buildings and structures**	To prevent or reduce the risk of physical, chemical, biological contamination during handling and storage	1. Buildings and structures used for growing, handling and storage of produce are constructed and maintained to minimize the risk of contaminating produce. 2. Grease, oil, fuel and farm machinery are segregated from handling, packing and storage areas to prevent contamination of produce. 3. Sewage, waste disposal and drainage systems are constructed to minimize the risk of contaminating the production site and water supply. 4. Lights above areas where produce and packing containers and materials are exposed, are either shatter proof or protected with shatter proof covers. In the event of a light breaking, exposed produce is rejected and equipment and packing containers and materials are cleaned. 5. Where equipment and tools that may be a source of physical hazards are located in the same building as produce handling, packing and storage areas, the equipment and tools are screened with a physical barrier or are not operated during packing, handling, and storage of produce.
2.2.8	**Cleaning and sanitation**	To prevent and reduce the risk of food contamination through application of approved standards of cleaning and sanitation	1. Packing, handling and storage areas and equipment, tools, containers and materials that may be a source of contaminating the produce are identified, and instructions are prepared and followed for cleaning and sanitation. 2. Appropriate cleaning and sanitation chemicals are selected to minimize the risk of these chemicals causing contamination of produce.

2.2.9	**Animals and pest control**	To prevent or reduce the risk of biological contamination through animals such as rodents, insects and feral animals and birds	1. Domestic and farm animals are excluded from the production site, particularly for crops grown in or close to the ground, and from areas where produce is harvested, packed and stored 2. Measures are taken to prevent the presence of pests in and around handling, packing and storage areas. 3. Baits and traps used for pest control are located and maintained to minimize the risk of contaminating the produce and packing containers and materials. The location of baits and traps is recorded.
2.2.10	**Personal hygiene**	To prevent or reduce the risk of physical and biological contamination by following hygiene standards	1. Workers have appropriate knowledge or are trained in personal hygiene practices and a record of training is kept. 2. Written instructions on personal hygiene practices are provided to workers or displayed in prominent locations. 3. Toilets and hand washing facilities are readily available to workers and are maintained in a hygienic condition. 4. Sewage is disposed of in a manner that minimizes the risk of direct or indirect contamination of produce.
2.2.11	**Storage and transport**	To prevent or minimize food contamination through safe storage and transportation of produce	1. Containers filled with produce are not placed in direct contact with soil where there is a significant risk of contaminating produce from soil on the bottom of containers. 2. Pallets are checked before use for cleanliness, chemical spills, foreign objects and pest infestation, and are cleaned, covered with protective material or rejected if there is a significant risk of contaminating produce. 3. Transport vehicles are checked before use for cleanliness, chemical spills, foreign objects, and pest infestation, and cleaned if there is a significant risk of contaminating produce. 4. Produce is stored and transported separate from goods that are a potential source of chemical, biological and physical contamination.
2.2.12	**Traceability and recall**	To ensure an effective system for identifying, tracing and recalling unsafe produce and removal from sale as well as to identify the cause of contamination and prevent re-occurrence.	1. Each separate production site is identified by a name or code. The name or code is placed on the site and recorded on a property map. The site name or code is recorded on all documents and records that refer to the site. 2. Packed containers are clearly marked with an identification to enable traceability of the produce to the farm or site where the produce is grown. 3. A record is kept of the date of supply, quantity of produce and destination for each consignment of produce. 4. When produce is identified as being contaminated or potentially contaminated, the produce is isolated and distribution prevented or if sold, the buyer is immediately notified. 5. The cause of any contamination is investigated and corrective actions are taken to prevent reoccurrence and a record is kept of the incident and actions taken.
2.2.13	**Training of workers and actors in supply chain**	Workers, employers and supply chain actors are trained in GAP and record keeping	1. Employers and workers have appropriate knowledge or are trained in their area of responsibility relevant to good agricultural practice and a record of training is kept.
2.2.14	**Documents and records**	To ensure GAP record keeping and	1. Records of good agricultural practices are kept for a minimum period of at least two years or for a longer period

		management	if required by government legislation or customers. 2. Out of date documents are discarded and only current versions are used.
2.2.15	**Review of practices**	To review the GAP practices on yearly basis or when needed, keep record of the corrective actions taken	1. All practices are reviewed at least once each year to ensure that they are done correctly, and actions are taken to correct any deficiencies identified. A record is kept of practices reviewed and corrective actions taken. 2. Actions are taken to resolve complaints related to food safety, and a record is kept of the complaint and actions taken.

Figure A2.4. The use of pesticides that are not approved for the crop and the continued use of fertilizers with high levels of heavy metals are common sources of chemical hazards

Figure A2.5. The types of microorganisms that cause illness are bacteria, parasites and viruses

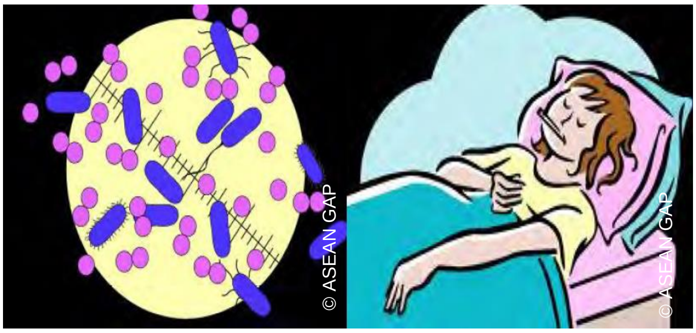


Figure A2.6. Physical hazards are foreign objects that become embedded in produce or fall into packages

Figure A2.7. The risk of chemical and biological contamination of produce from previous use of the site and from adjoining sites must be assessed

Figure A2.8. For side-dressing produce grown close to the ground, use only fully composted materials or treated proprietary organic products, and do not apply them within two weeks of harvest

Figure A2.9. The location of organic materials beside waterways used to irrigate or wash produce can lead to biological contamination of produce

Figure A2.10. Chemicals and bio-pesticides used on crops must be approved by a competent authority in the country where the crop is grown and intended to be traded.

Figure A2.11. Chemicals must be stored in a well-lit, sound and secure structure, with only authorized people allowed access.

Figure A2.12. Empty chemical containers are not re-used and are kept secure until disposal

Figure A2.13. Domestic and farm animals must be excluded from the production site, particularly for crops grown in or close to the ground, and from areas where produce is harvested, packed and stored

Figure A2.14. Toilets and hand washing facilities must be readily available to workers and maintained in a hygienic condition

Annex 2.3. Module for environmental management ASEAN GAP

S.No	GAP requirement	Objectives	Required practice (s)
2.3.1	**Sites history and management**	To prevent or minimize the risk of hazards causing environmental harm while selecting site for production and postharvest handling	1. Sites used for production comply with country regulations that restrict production at high altitudes or on steep slopes. 2. For new sites, the risk of causing environmental harm on and off the site is assessed for the proposed use and a record is kept of all potential hazards identified. The risk assessment shall consider: - the prior use of the site, - potential impacts of crop production and postharvest handling on and off the site, and - potential impacts of adjacent sites on the new site. 3. Where a significant risk is identified, either the site is not used for crop production and post-harvest handling or measures are taken to prevent or minimize the potential hazards. 4. property layout map is available showing the location of: a. crop production sites, b. environmentally sensitive areas and highly degraded areas, c. chemical storage and mixing areas, chemical application equipment cleaning areas, and postharvest chemical treatment areas, d. areas or facilities for storage, mixing and composting of fertilizers and soil additives e. water courses, storage sites, and significant drainage lines, run-off areas and discharge points, and f. property buildings, structures and roads. 5. Highly degraded areas are managed to minimize further degradation. 6. Management of site activities conforms to country environmental legislation covering air, water, noise, soil, biodiversity and other environmental issues.
2.3.2	**Planting material**	To minimize or prevent the risk of chemical	1. To minimize chemical usage and nutrient runoff, planting material is selected for disease resistance and compatibility with site properties such as soil type and

		contamination by selecting disease resistant and environmentally compatible planting materials for reduced use of fertilizers and pesticides	nutrient levels.
2.3.3	**Soil and substrates**	To minimize or prevent soil degradation through soil erosion, salinity, alkalinity, sodicity and acidity land through improved land, irrigation and crop management practices	1. The intended production practices are suitable to the soil type and do not increase the risk of environmental degradation. 2. Where available, soil maps are used to plan rotation and production programs 3. Cultivation practices that improve or maintain soil structure and minimize soil compaction and erosion are used. 4. The use of chemical fumigants to sterilize soils and substrates is justified and a record is kept of the location, date, product, application rate and method, and operator name.
2.3.4	**Fertilizers and soil additives**	To prevent or minimize environmental harm through chemical contamination using improved and sites/location specific fertilizers and soil additives management	1. Nutrient application is based on recommendations from a competent authority or on soil, leaf or sap testing to minimize nutrient runoff and leaching. 2. Areas or facilities for storage, mixing and loading of fertilizers and soil additives and for composting of organic matter are located, constructed and maintained to minimize the risk of environmental harm on and off the site. 3. Equipment used to apply fertilizers and soil additives is maintained in working condition and checked for effective operation at least annually by a technically competent person 4. The application of fertilizers and soil additives is recorded, detailing the name of the product or material, date, treatment location, application rate and method, and operator name.
2.3.5	**Irrigation and water management**	To prevent or minimize environmental harm through use of safe irrigation water and efficient of drainage and run off water	1. Irrigation use is based on crop water requirements, water availability, soil moisture levels, and consideration of environmental impact on and off the site 2. An efficient irrigation system is used to minimize wastage of water and the risk of environmental harm on and off the site. 3. The irrigation system is checked for operational efficiency during each use, according to manufacturer's instructions or other appropriate methods, and maintained to ensure efficient delivery. 4. A record is kept of irrigation use, detailing crop, date, location, volume of water applied or duration of irrigation, and name of person who managed the irrigation activity. 5. Water collection, storage, and use is managed to comply with country regulatory requirements. 6. Water used from sources that may cause environmental harm to land and soil, waterways and sensitive areas is managed or treated to minimize the risk of environmental harm.

			7. Water from toilets and drainage systems are disposed of in a manner that minimizes the risk of environmental harm on and off the site. 8. Water discharged from the property, including waste water from harvesting, cleaning and handling operations, is managed or treated to minimize off site environmental harm.
2.3.6	**Chemical (Agrochemicals)**	To prevent or minimize loss /damages to the local ecosystem through safe and approved use of agrochemicals	1. Employers and workers have been trained to a level appropriate to their area of responsibility for chemical application. 2. If the choice of chemical products is made by advisers, proof of their technical competence is available. 3. Crop protection measures are appropriate for the control of pests and based on recommendations from a competent authority or monitoring of crop pests. 4. Integrated pest management systems are used where possible to minimize the use of chemicals. 5. Chemicals are only obtained from licensed suppliers. 6. Chemicals used are approved for the targeted crop by a competent authority in the country of application, and up to date documentation is available to demonstrate the current approval status. 7. Chemicals are applied according to label directions or a permit issued by a competent authority. 8. A rotation strategy for chemical application and other crop protection measures are used to avoid pest resistance. 9. The application of chemicals (ground and aerial) is managed to minimize the risk of spray drift to neighbouring properties and environmentally sensitive areas. 10. Appropriate volumes of chemicals are mixed to minimize the amount of surplus chemical remaining after application. 11. Surplus chemical mixes and tank washings are disposed of in a manner that minimizes the risk of environmental harm on and off the site. 12. Equipment used to apply chemicals is maintained in working condition and checked for effective operation at least annually by a technically competent person. 13. Chemicals are stored in a well-lit, sound and secure structure, with only authorized people allowed access. The structure is located and constructed to minimize the risk of contaminating the environment and equipped with emergency facilities in the event of a chemical spill. 14. Chemicals are stored in the original container with a legible label and according to label directions or instructions from a competent authority. If a chemical is transferred to another container, the new container is clearly marked with the brand name, rate of use and withholding period. 15. Empty chemical containers are not re-used and are kept secure until disposal. 16. Empty chemical containers are disposed of according to relevant country regulations and in a manner that minimizes the risk of causing environmental harm on and off the site. Official collection and disposal systems are

			used where available. 17. Obsolete chemicals, which are unusable or no longer approved, are clearly identified and kept secure until disposal. 18. Obsolete chemicals are disposed of through official collection systems or in legal off-site areas. 19. The application of chemicals is recorded for each crop, detailing the chemical used, reason for application, application date, treatment location, application rate and method, weather conditions, and operator name. 20. Where applicable, a record of chemicals held in storage is kept, detailing chemical name, date and quantity obtained and date when completely used or disposed of. 21. Fuels, oils, and other non-agrochemicals are handled, stored and disposed of in a manner that minimizes the risk of contaminating the environment. 22. The application, storage, and disposal of chemicals used after harvest, such as pesticides and waxes, follow the same practices as described in the Chemicals section. 23. A waste management plan is documented and followed, including identifying types of waste products generated by property activities and using practices to minimize waste generation, reuse or recycle waste and store and dispose of waste.
2.3.7	**Harvesting and handling produce**	To prevent or minimize damage to the environment through safe and approved use of chemicals used for application such as pesticides, fungicides, insecticides, weedicides, fumigants and wax used for surface coating	All the procedures and safety protocols given in S.No. 6 for chemicals and agrochemicals are followed.
2.3.8	**Waste and energy efficiency**	To prevent or minimize environmental harm through safe, efficient and improved waste water and emergency use efficiency	1. Consumption of electricity and fuel is reviewed and efficient operating practices are identified and used. 2. Machinery and equipment are serviced to maintain operational efficiency or are replaced. 3. Property activities comply with country regulations covering the protection of endangered plant and animal species. 4. To conserve native plant and animal species, access and activity is managed in significant remnant native vegetation areas, wildlife corridors, and vegetation areas on and near the banks of waterways. 5. Measures are used to control feral animals and environmental pests. 6. The generation of offensive odour, smoke, dust, and noise is managed to minimize the impact on neighbouring properties.
2.3.9	**Biodiversity**	To preserve and	1. Local legislations and laws are followed for

		protect local biodiversity through safe crop management practices	preservation and protection of local biodiversity for improved ecosystems
2.3.10	**Air**	To prevent or minimize environmental pollution through safe, efficient and approved management of the farm operations	1. Employers and workers have appropriate knowledge or are trained in their area of responsibility relevant to good agricultural practices and a record of training is kept. 2. Records of good agricultural practices are kept for a minimum period of at least two years or for a longer period if required by legislation or customers 3. Out of date documents are discarded and only current versions of documents relevant to good agricultural practice are used. 4. All practices are reviewed at least once each year to ensure that they are done correctly, and actions are taken to correct any deficiencies identified or if changes occur to environmental regulations. 5. A record is kept to show that all practices have been reviewed and any corrective actions taken are documented. 6. Actions are taken to resolve complaints related to environmental management, and a record is kept of the complaint and actions taken.
2.3.11	**Trainings**	To prevent or minimize environmental hazards through awareness and skills of employers and workers engaged in farm	1. Workers are trained on hazards and hazards safe management 2. Record of the training and compliances are maintained.
2.3.12	**Documents and records**	To maintain documents and record as evidence for traceability and implementation of GAP	1. Documents and record for traceability related to environmental safety are maintained at least for two years 2. Evidence for implementation of safety measures and GAP practices are available to the auditors and investigators
2.3.13	**Review of practices**	To ensure compliance to GAP and corrective actions taken through regular or need based review of practices	1. Record and documents of practices reviewed and compliances/course correction taken are available 2. Record of the complaints and corresponding correction actions taken are maintained.

Figure A2.15. For new sites the risk of causing environmental harm on and off the site is assessed for the proposed use

Figure A2.16. Highly degrade areas must be managed to minimize further degradation

Figure A2.17. To minimize the risk of soil erosion, use natural contour lines and organic mulches

Figure A2.18. The use of chemical fumigants to sterilize soils and substrates is justified

Figure A2.19. Storage, mixing and loading areas for fertilizers and soil additives should be positioned to minimize the risk of pollution of waterways and groundwater

Figure A2.20. Chemicals are applied according to the label directions or a permit issued by a competent authority

Figure A2.21. Waste management and documentation

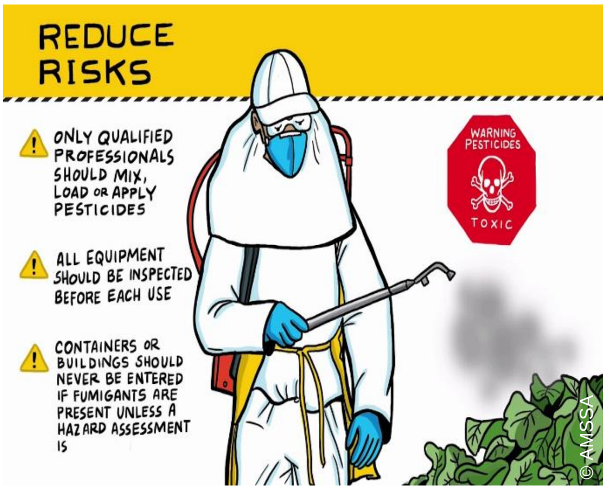
Annex 2.4. Module Worker Health, Safety and Welfare Module–ASEAN GAP

S.No	GAP requirement	Objectives	Required practice (s)
2.4.1	**Chemicals**	To ensure workers health, safety and welfare through prevention or minimization of exposures to the hazardous effects of chemicals.	1. Chemicals are handled and applied by authorized workers with appropriate knowledge and skills. 2. Chemicals are stored in a well-lit, sound and secure structure, with only authorized people allowed access. The structure is located and constructed to minimize the risk of contaminating workers and equipped with emergency facilities in the event of a chemical spill. 3. Chemicals are stored in the original container with a legible label and according to label directions or instructions from a competent authority. If a chemical is transferred to another container, the new container is clearly marked with the brand name, rate of use and withholding period. 4. Where there is a significant risk of chemical contamination of workers, Material Safety Data Sheets or safety instructions from chemical labels are readily available. 5. Facilities and first aid measures are readily available to treat workers contaminated with chemicals. 6. Accident and emergency instructions are documented and displayed in a prominent location within or close to the chemical storage area. 7. Workers handling and applying chemicals and entering newly sprayed sites are equipped with suitable protective clothing and equipment for the chemical used. 8. Protected clothing is cleaned and stored separately from crop protection products. 9. Access to sites where chemicals are being applied or newly applied is restricted for an appropriate period relevant to the chemical used. 10. required, chemical application in areas of public access is marked with warning signs.
2.4.2	**Working conditions**	To provide safe, healthy and	1. Working conditions are suitable for workers and protective clothing is supplied where conditions are

		conducive work conditions for workers	hazardous to workers. 2. All farm vehicles, equipment and tools, including electrical and mechanical devices, are adequately guarded, maintained and inspected on a regular basis for potential hazards to users. 3. Safe manual handling practices are followed to minimize the risk of injury from lifting heavy objects and excessive twisting and reaching movements.
2.4.3	**Personal hygiene**	To prevent or minimize biological, physical and chemical contamination through implementation of personal hygiene practices by farm family and workers and provision of personal hygiene facilities at the farm	1. Workers have appropriate knowledge or are trained in personal hygiene practices and a record of training is kept. 2. Written instructions on personal hygiene practices are provided to workers or displayed in prominent locations. 3. Toilets and hand washing facilities are readily available to workers and are maintained in a hygienic condition. 4. Sewage is disposed of in a manner that minimizes the risk of contamination of workers. 5. Where employers are required to provide medical and health cover, any serious health issue is reported to the relevant health authority. 6. Where required, foreign workers complete mandatory medical checks and a record is kept. 7. Measures are taken to minimize the presence of animals and pests with infectious disease in production sites and around handling, packing and storage areas.
2.4.4	**Worker welfare**	To ensure welfare and well-being of workers and productivity of the farm or packing shed through prevention of exploitation due to age, gender, race and any other reason	1. Where provided by an employer, living quarters are suitable for human habitation and contain basic services and facilities. 2. The minimum working age shall comply with country regulations. Where regulations are absent, workers shall be older than 15 years of age.
2.4.5	**Trainings**	New workers should be informed and trained about the risks to their health and safety and safety measures	1. New workers are informed about the risks associated with health and safety when starting at the worksite.
2.4.6	**Documents and records**	To ensure implementation of GAP for protection of workers health, safety and welfare.	1. Documents and records provide evidence that good agricultural practices have been implemented to protect worker health, safety and welfare. 2. Workers trainings record are available for safety and well-being. 3. Evidence of regular review of practices for workers welfare and safety is available for verification
2.4.7	**Review of practices**	To ensure workers safety and wellbeing through regular review of practices.	1. Review practices are documented and implemented for workers safety and welfare. 2. Records of compliance standards to workers safety and wellbeing is available for assessment and verification. 3. Record of Complaints related to worker health, safety and welfare investigated and actions taken to resolve the Complaint are maintained.

Figure A2.22. Protection from the hazardous effects of chemical must be complied with

Figure A2.23. Posters and signs in the work area help to reinforce instructions for workers



Annex 3: GAP Check Lists

		FORM-1
	CHECK LISTS FOR FARMERS' FIELD	
Site inspection		
S.No	**Parameter**	**Required compliance /record keeping/documentation**
1	Name of crop	
2	Total sown area	
3	Area of GAP registered crops/plant population	
4	Land preparation before sowing time	
5	Land preparation after sowing	
Surrounding areas		
1	Surrounding areas of GAP field	
2	Are there any other crops cultivated in surrounding areas of GAP field?	☐Yes☐No
3	Distance between GAP field and toilet	
Seed selection		
1	Name of crop variety	
2	Any plant parts for plant propagation	
3	Seed/plant propagation source	

Cultivation method		
1	Row and plant spacing	
2	Status of inter-cropping	□Yes□No
3	Crop duration	

Fertilizer application						
S.No.	**Parameter**	**Inspection record**				
		Fertilizer used	**Fertilizer rate (kg/acre)**	**Frequency**	**Mode of application**	**Application date**
1	Fertilizer used before sowing					
2	Fertilizer used after sowing					
3	Farmyard manure used					
4	Soil additives and other supplements used for GAP crop					

FORM-1

CHECK LISTS FOR FARMERS' FIELDS						
Pesticides/Fungicides Application						
S.No.	**Parameter**	**Inspection record**				
		Pesticides/fungicides used	**Pesticides/ fungicides rate (kg/acre)**	**Frequency**	**Mode of application**	**Application date**
1	Pesticides/fungicides used before field inspection					
2	Pesticides/fungicides currently used					
3	Pesticides/ fungicides storage methods					
4	Warehouse existences					

Irrigation and source of irrigation water		
Sr.No.	**Parameter**	**Inspection record**
1	Source of irrigation water	
2	Distance between irrigation source and GAP field	
3	Irrigation System	
Postharvest Practices		
1	Packaging and Cleaning	
2	Storage and Transportation	
3	Warehouse existences for harvested crops	
Personal Hygiene and Worker welfare		
1	Total number of workers	
2	Number of workers who received the trainings on “Systematic Pesticide Application Methods”	
3	Number of workers who received other trainings	
4	Compliance of Personal Hygiene	
5	Existences of housing for the workers	
6	Work done for personal hygiene and worker welfare	

FORM-2		
CHECK LISTS FOR FARMERS’FIELD		
C- Compliance	**NC- Non Compliance**	**NA- Nail**

1. Site Selection		**C**	**NC**	**NA**
1	The site and its surrounding areas used for production of GAP crops are not contaminating with any chemical and biological hazards.			
2	The layout map of the site and a record are kept of official document of land use permission (Form-7).			
2. Irrigation				
1	The results of water test are kept. (rain water, water from river, stream, creeks, tube well and ponds, underground water)			

2	The water used for irrigation are not coming from livestock farms, hospitals, industries, waste water and any sources that may cause environmental harm.			
3. Seed/Seedling				
1	A record is kept of source of supply, amount of supply and the date of supply for seeds, seedlings and plant propagations.			
2	A record is kept of chemicals used for seeds, seedlings and plant propagations.			
4. Fertilizers and Soil Additives				
1	The fertilizers and soil additives used for GAP crop production are free from chemical and biological contaminations that may be harmful on and off the site.			
2	The results of soil test are kept.			
3	The farm manure are used after making thoroughly compost and a record is kept.			
4	The registered products (fertilizers and soil additives) are only purchased from licensed suppliers and used for crop production.			
5	Areas or facilities for storage, mixing and loading of fertilizers and soil additives and for composting of organic matter are located, constructed and maintained to minimize the risk of environmental harm on and off the site.			
6	Produce is stored in areas separated from the chemicals.			

FORM-2				
CHECK LISTS FOR FARMERS'FIELD				
C- Compliance	**NC- Non Compliance**	**NA- Nail**		
5. Agrochemicals and Other Chemicals		**C**	**NC**	**NA**
1	Compliance of Integrated Pest Management System – IPM			
2	The registered chemicals are only purchased from licensed suppliers and used for crop production.			
3	Compliance of Post-Harvest Intervals (PHIs)			
4	Compliance of recommended dosage and systematic application methods.			
5	Systematic chemical application methods are observed and followed exactly.			

6	Compliance of using PPE by the workers whenever they use pesticides.			
7	Chemicals are carefully disposed in the areas of separate places far away from water sources and a record is kept of all actions taken.			
8	After pesticide application, personal hygiene practices are observed and followed exactly. Pesticide spraying equipment are also cleaned.			
9	Work done for precaution measures for recently pesticide sprayed areas.			
10	Chemicals are stored in the areas separated from other materials and goods.			
11	The chemicals obtained, stored, used, application and disposals of chemicals are systematically handled and recorded. A record is kept of all actions taken.			
12	Fuels, oils, and other non-agrochemicals are handled, stored and disposed of in a manner that minimizes the risk of contaminating produce.			
6. Agriculture and Other Related Materials				
1	The farm machinery and farm implements are cleaned.			
2	Equipment, materials that contact produce and containers used for storage and other materials are cleaned not to contaminate the produce.			
3	Waste, chemicals, other dangerous subsistence and materials are clearly identified and are not used for storage and holding produce.			

FORM-2				
CHECK LISTS FOR FARMERS'FIELD				
C- Compliance	**NC- Non Compliance**	**NA- Nail**		
7. Harvesting and Handling Produce		**C**	**NC**	**NA**
1	Compliance of proper harvesting method at good maturity stage.			
2	Harvested produce is not placed in direct contact with soil or the floor of handling, packing areas.			
3	Packaging materials are cleaned and systematically stored.			
4	Before storage of produce, the warehouses are carefully cleaned.			

5	Water used for cleaning of produce and any parts of produces are clean.			
6	Identification and compliance of recommended places for having meals.			
8. Storage and Transport				
1	Harvested produce is not stored and transported in direct contact with animals, chemicals and fertilizers.			
2	Transport vehicles are checked before used and cleaned.			
3	Transport vehicles are also checked for chemical waste, pest infestation and other materials.			
9. Building and Structure				
1	Building and structure used for packaging, handling and storage of produce are constructed and maintained to minimize the risk of contaminating produce or separate places for those actions are identified and measures are taken.			
10. Animals and Pest Control				
1	Domestic and farm animals are excluded from the production site particularly for the areas where produce is harvested, packed and stored.			
11. Documents and Records				
1	Records of good agricultural practices are kept for a minimum period of at least two years. A record is kept of current practices taken in the format form.			
	• Authorized person for chemical use/application • Risk assessment record • Record of practices taken • Seed, seedlings and any plant parts used for plant propagation • Chemicals stored/ used for crop production			
CHECK LISTS FOR FARMERS'FIELD				
C- Compliance	**NC- Non Compliance**	**NA- Nail**		
		C	**NC**	**NA**
	• Pesticide application • Fertilizers and soil additives • Record of irrigation • Chemicals obtained and used after harvesting • Action plan for personal hygiene and Plant Protection • Training Attended • Review of practices			

	• Other records (field maps,.)			

12. Traceability and recall				
1	Packed containers are clearly marked with an identification and registration number to enable traceability of the produce to the farm or site where the produce is grown.			
13. Training				
1	Employers and workers are trained to have appropriate knowledge in their area of responsibilities relevant to good agricultural practices.			
14. Personal Hygiene and Worker welfare				
1	Written instructions on personal hygiene practices are displayed in prominent locations or are provided to workers.			
2	All actions taken are emphasized on personal hygiene of the workers from packaging sites and packaging, washing and produce treatment is clean.			
3	Toilets, water used for washing and cleaning for personal hygiene practices are easily provided to workers.			
4	All actions taken are emphasized on personal hygienic and worker welfare.			

global agriculture & food security program

Contact information

FAO Representation in Myanmar
FAO-MM@fao.org
www.fao.org/myanmar/fao-in-myanmar/en/

Food and Agriculture Organization of the United Nations
Nay Pyi Taw, Myanmar

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