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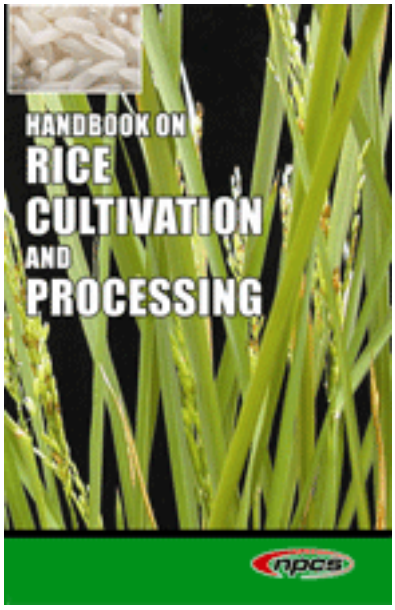
Handbook on Rice Cultivation and Processing



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Rice is the staple food of over half the world population. Rice is normally grown as an annual plant, although in tropical areas it can survive as a perennial crop and can produce a ratoon crop for up to 30 years. The rice plant can grow to 1 to 1.8 m tall, occasionally more depending on the variety and soil fertility. Since its origin, the spread of rice cultivation is extensive and rice is now being grown wherever water supply is adequate and ambient temperature are suitable. The rice grain is covered with a woody husk or hull, which is indigestible and is to be removed in the first step during processing for making the rice edible. Rice cultivation is well suited to countries and regions with low labor costs and high rainfall, as it is labor intensive to cultivate and requires ample water. Rice can be grown practically anywhere, even on a steep hill or mountain. The traditional method for cultivating rice is flooding the fields while, or after, setting the young seedlings. This simple method requires sound planning and servicing of the water damming and channeling, but reduces the growth of less robust weed and pest plants that have no submerged growth state, and deters vermin. While flooding is not mandatory for the cultivation of rice, all other methods of irrigation require higher effort in weed and pest control during growth periods and a different approach for fertilizing the soil. Drying is an essential step in the processing and preservation of paddy; it is the process that reduces grain moisture content to a safe level for storage. Milling is a crucial step in post production of rice. The basic objective of a rice milling system is to remove the husk and the bran layers, and produce an edible, white rice kernel that is sufficiently milled and free of impurities. India is the second largest rice producing country of the world after China. India also grows some of the finest quality aromatic rice of which basmati is the most high quality rice.
This book basically deals with history, origin and antiquity of rice, seed rice and seed production, harvest and post harvest operations, water management practices for rice, diseases and pests of rice and their control, application of biotechnology in aromatic rice improvement, traditional methods of parboiling, modernization of parboiling process, solvent extractive rice milling, general types of quick cooking rice processes, dry milled rice products in brewing, breakfast cereals, rice flakes, puffed rice, rice in multi grain cereals etc.

The present book contains cultivation and processing of rice in various ways. The book is very resourceful for the entrepreneurs, technocrats, research scholars etc.

Tags
How to start a rice farming business, How to Start a Rice Production Business, How to Start Food Processing Industry in India, How to Start Growing Rice, How to Start Rice Farming and Processing Business, How to Start Rice Farming With Modern Rice Farming Techniques, How to Start Rice Processing Industry in India, brewing with flaked rice, challenges of rice production, Cultivation of Rice in India: Conditions, Methods and Production, Food Processing Industry in India, Harvest, Drying, and Storage of Rough Rice, How rice is made, How Rice is Processed, How to Process Rice after being harvested from the Farm, How to Start a Food Production Business, hybrid rice production , Instant rice, Methods of Planting Rice, Milling and processing of rice, Most Profitable Food Processing Business Ideas , Most Profitable Rice Processing Business Ideas, parboiled rice processing technology, Parboiling of Paddy, parboiling of rice, Procedures to Start a Successful Rice Farming Business, Process of Making Parboiled Rice, Processing and Milling of Parboiled Rice, Production of infant foods, Production of Rice Breakfast Cereal food, Quick cooking rice , Rice Beer, rice cultivation and processing book, Rice Cultivation and Processing Business Plan, rice cultivation process, Rice Farming Business - Startup Business, Rice farming: every stage from start to finish, rice seed production manual, Rice Seed Production Technology, Starting a Rice Farm, Starting a Rice Processing Business, storage of rice, technology book on rice

production

Content:

Sample Chapter:

The origin of rice (Oryza sativa L.) has interested some eminent botanists and provisional inferences were made in the first half of this century. A symposium was held in Delhi during 1950 on the origin of cultivated plants of South Asia and since then research on the origin and cytogenetics of rice has been intensified in India and in Japan. Research publications on the taxonomy evolution and cytogenetics of rice and its relatives have appeared in many journ als. A recent review by Nayar gives a comprehensive bibliography and a critical discussion about Origin and Cytogenetics of Rice . Some supplementary information is given by Sampath and these two articles have to be consulted for details. It is here proposed to give the salient findings and to mention some of the topics on which further studies are needed.

ANTIQUITY

Formerly literary texts as well as traditions were cited to establish the antiquity of rice cultivation in a particular region. Because of difficulties in establishing the age of a particular text and in interpreting the statements pertaining to cereals archaeological evidence is to be preferred. Where rice grains chaff or husks are detectable in pottery bricks or mud constructions it is possible to identify the material with some confidence and to establish its age by dating with radiocarbon.

The first detailed study of an archaeological rice sample from India was from carbonized grains excavated from Hastinapur north of Delhi and was dated as being between 1100 and 700 B.C. Subsequent archaeological evidence on rice in India has been reviewed by Buth and Saraswath. They consider the specimens collected from Atranjikera in Uttar Pradesh to be the oldest found so far and estimate their period of occurrence to range from 1500 1000 B.C. Vishnu Mittre has given a detailed discussion about the origin antiquity and spread of rice cultivation in India. As regards China another ancient region of rice cultivation pottery excavated from Yang Shao has been found to carry imprints as well as rice husks. The period of that culture is estimated at 2000 B.C. but a greater antiquity has also been claimed. The region covering Burma Thailand and Cambodia is well suited to rice cultivation and has also a large population of wild rices. Therefore the discovery by a team of American archaeologists of the most ancient finds of rice from excavations in Thailand is of interest. The work reviewed by Solheim suggests that these finds reveal the first agricultural beginning in southern Asia important enough to be termed a revolution. The specimens include horticultural plants as well as rice husks. The dating suggests that these specimens belong to the period ranging from 5000 4000 B.C. This antiquity may be accepted provisionally and it may be inferred that rice cultivation spread to Vietnam Taiwan China as well as to India from this centre. However an independent and parallel origin in Assam Bengal and Kerala cannot at present be dismissed.

SPECIES ANCESTRAL TO RICE

It has long been recognized that the wild species of Oryza closely related to O. sativa are widely distributed in India Burma Thailand and Cambodia. These wild populations can be grouped into at least two taxa but the distinctions are not clear cut as intermediates have been arising as a result of natural crossings. If the division into taxa is to be made it is necessary to apply the rules of nomenclature and decide on the valid names of the two species. This is a controversial issue as may be understood from the following account. One taxon of restricted distribution is found on the margins of ponds is partly floating and is potentially perennial. This species is distinguished from its close relative which is seasonal having slender grains and longer anthers in addition to some differences in plant and panicle characters. This species was used to be called Oryza perennis (Moench). This specific name is rejected as invalid by Tateoka in his comprehensive revision of the genus Oryza. A discussion about this and allied taxonomic difficulties is included in the book Rice Genetics and Cytogenetics. In a subsequent chapter of this monograph details of taxonomy and species relationship are elaborated. Since the specific name perennis is widely used and is also convenient to conserve as a valid name Sampath published an emended

description from a specimen collected in Orissa. It is therefore permissible to consider the Orissa type to be a subspecies of a widespread varying and long anthered wild rice. The other taxon has bolder grains shorter anthers and generally stouter awns. This species has large populations and shows greater variation. Large populations of this species can be seen beside the railway track on Borrow Pits along the east coast of India north of Vijayawada and including Bengal. These plants flower during October when their conspicuous pink awns make the specific name O. rufipogon Griffith. It is possible that this species evolved from hybrids between O. sativa and O. perennis. Moench emend. Sampath because it has been repeatedly observed in many countries that where O. perennis grows adjacent to rice plots cross pollination from wild rice takes place. The extent of crossing is low but in the course of time a weed population builds up in the rice fields since the hybrid plants shed their seeds which remain dormant till the next season. In the course of generations a diversified population can evolve from the hybrids and can invade new habitats. It is also possible that the very large populations may be grouped together as a single species to include genotypes which had evolved from O. perennis before human intervention as an adaptation to habitats liable to drought.

A theory has been advanced that climatic changes during the Pleistocene Period induced physiological stresses in the herbaceous flora and the evolution of seasonal forms the existing perennial ones was accelerated. An exposition of this theory as pertaining to the Gramineae of Asia is made by R.O. Whyte (in press). To apply this concept to rice is to infer the changes as perennial climatic stress seasonal human selection cultivated rice. The term genome which is explained later in this book has to be used for supporting this hypothesis. The symbol A is used for the genome present in a species at the diploid level in O. perennis O. rufipogon and also in O. sativa. The theory of evolution precludes the separate creation of a species. Therefore the species having the A genome are interrelated and their evolution may be traceable. A simplified statement of the ancestry of the cultivated rice is as follows. The perennial long anthered species is the ultimate ancestor but possibly another taxon with bolder grains and seasonal habit was the immediate ancestor. For details the review of Nayar may be seen. Under this topic there is a need for further research to arrive at a firm conclusion.

GENETIC PROCESS INVOLVED IN DOMESTICATION

For the human selection to operate there must be genetic variability present in populations which must be responsive to the procedures of primitive agriculturists. The details of cultivation practices in ancient times cannot be traced but it can be inferred that in some areas the scrub or the jungle was cut burnt crudely leveled and the seeds of crops were sown. In river valleys and deltas the procedures would be slightly different suggesting a more advanced agriculture. The method used by primitive agriculturists for harvesting and seed selection is not known. Initially the seeds of wild rice must have been used. The perennial wild rice is partly out crossing hence heterozygous and different populations show differences in genetic composition. Hybridization between different genotypes followed by inbreeding would lead to rapid changes in plant characteristics. Mutations for nonshedding awnless grains would be intensively selected by the primitive agriculturists. Sampath has suggested that hybridity in the molecular structure of some key enzymes could have played a part in the evolution of O. sativa. Studies on population genetics of the wild rices of the world have been carried out by Dr H.I. Oka and his collaborators at the National Institute of Genetics Misima. These studies contribute substantially to an understanding of the origin of O. sativa. Two of his collaborators gave experimental findings and summarized his interpretation. In a joint contribution the dynamics of plant domestication as applicable to rice is discussed. In view of such significant studies any further advance under this topic can come only as the result of combined cytogenetic and biochemical studies on hybrids and hybrid progenies of wild rices.

Breeding

Rice breeding in India started in 1911 in undivided Bengal with the appointment of Dr G.P. Hector as Economic Botanist with his headquarters at Dacca which is now in Bangladesh. In 1912 Madras province had the first crop specialist fully devoted to rice. The period from 1911 1979 may be considered under three distinct periods as far as rice breeding in India is concerned viz. of mainly pure line selections and very few hybridizations of inter racial hybridization between japonicas and indices and of inter racial hybridization with semi dwarfs especially Taiwanese indices.

Prior to 1930 Bengal and Madras were the only provinces which had full time specialists for the crop. When the Indian Council of Agricultural Research was established in 1929 it initiated rice research projects in many states which did not have a rice programme and this gave an impetus to the development of rice research in the country and by 1950 there were 82 research stations devoted to rice in 14 states of India. These research stations released 445 improved varieties mainly by the pure line method of selection. Of course a few (e.g. Co. 15 Co. 16 Co. 25 Co. 26 Co. 29 Co. 30) were hybrid derivatives from indica crosses but numerically they were insignificant when compared to those evolved through pure line selections. The number of varieties released from each state is given below.

Ramiah and Rao have delineated the development of Rice Research Stations in India. The establishment of these different stations was prompted by the need to cater for different ecological conditions. Ghose et al. had listed the broad breeding objectives which made possible the development of 445 improved varieties in the country. They were (1) Earliness (2) Deep water and flood resistance (3) Lodging resistance (4) Drought resistance (5) Non shedding of grains (6) Dormancy of seed (7) Control of wild rice (18) Disease resistance and (9) Higher response to heavy manuring.

Table 1. The number of varieties released by different states through selection and hybridization

Thus the earlier breeding efforts were directed towards the development of varieties adapted to specific stress situations or for resistance to diseases prevalent in the region or what the Japanese called ecological breeding . When synthetic fertilizers began to be popular after World War II efforts were made to identify varieties which respond to heavy manuring. There were no major pest problems and the progress though not spectacular did not pose possibilities of serious disaster. Through pure line selection the advantages of natural selections over centuries had been fully made use of and there were no problems of antagonism involved in the introduction of new genes to an incompatible environment. The surviving genotypes seemed to be more suited to their environment underscoring the significance of survival and adaptation in evolution.

After the establishment of the Central Rice Research Institute in 1946 at Cuttuck there had been a systematic screening of exotic types from the genetic stocks and many Chinese Japanese Taiwanese and Russian types were tested for the purpose of direct introduction in the country. The result showed that the early duration local varieties like Benibhog were superior to the exotic introductions. Notable among the Chinese introductions were Ch. 4 Ch. 45 Ch. 55 Ch. 62 and Ch. 63 of these Ch. 45 proved to be a good yielder combined with earliness and Helminthosporium resistance and had been used as a donor in some of the modern varieties.

Prior to 1947 Chinese varieties were first introduced in Kashmir Valley possibly due to reasons of geographical proximity or contiguity and have been found suitable and so extensively cultivated. The most notable of these introductions is Ch. 1039 which is the leading variety of Kashmir Valley even today. Others are Ch. 27 Ch. 47 Ch. 962 Ch. 971 and Ch. 972 .

Though the Chinese types were fairly successful the Japanese and Russian introductions were found unsuitable under Indian conditions mainly because of their low yield unacceptable grain qualities and susceptibility to blast.

Period of inter racial hybridization between japonicas and indicas

The end of the Second World War and the subsequent population explosion stimulated the Food and Agricultural Organization of the United Nations to take up the problem of improving production of this major Asian and world cereal on an international basis and the result was a collaborative project of japonica × indica hybridization in South East Asian countries. Japan had started using chemical fertilizers from the beginning of this century and so japonicas the cultivated rices of Japan showed response to fertilizer under Japanese conditions up to 60 100 kg N/ha whereas the indicas cultivated types in Asia responded to N fertilizer only up to 20 30 kg N/ha.

The rationale of the F.A.O. project was to transfer the high yielding ability and response to heavy fertilizer inputs that characterize the japonicas into the local indica varieties which were adapted to their respective conditions of culture and had tolerance to the prevalent diseases and pests of the region.

A parallel scheme of japonica × indica hybridization was also drawn up by the Indian Council of Agricultural Research (ICAR) with the same objectives of identifying varieties with response to fertilizer and having the major features of the local varieties of the different states.

These two projects used 192 improved indica varieties selected by the participating Asian countries and Indian states and produced a total of 710 different japonica × indica hybrids. F1 seeds of these hybrids were distributed to the different participating countries or states for growing the F2 and subsequent generations in their respective regions to breed varieties suited to those agro climatic conditions.

These projects could claim only very limited success as only four varieties were released from the seven hundred and odd hybrid combinations. Malinja and Mahsuri in Malaysia Adt. 27 in Tamil Nadu state of India and Circna in Australia were the varieties named.

Another scheme was lunched by Central Rice Research Institute (CRRI) in 1960 to evolve high yielding fertilizer responsive hybrid varieties with japonica in 11 states. The development of the semi dwarf varieties in Taiwan and Philippines and their introduction into India put an abrupt end to this scheme in 1966 even before the results could be properly assessed.

But in another later attempt at Central Rice Research Institute Rao and Nagaraju achieved remarkable success in the development of japonica×indica hybrids fully achieving the objectives envisaged in the original international and national hybridization projects. Their success might be attributed to the choice of short statured japonicas (as against the tall ones previously used) grown in South Japan which climatically is fairly similar to Taiwan (and not from Hokkaido the coldest region where rice is grown). So varieties adapted to mild temperate region were seen to be more productive under tropical conditions than those from extremely cold temperate zone. This emphasises the importance of selecting suitable parents with adaptability in rice improvement/hybridization programmes.

During the period of japonica×indica hybridization time and again it was stressed that the japonicas had high yielding ability and response to fertilizer. But in India the introduced japonicas had been a total failure except in the hills and some cool areas. Japonicas were both photoperiod and temperature sensitive and so flowered in 35 40 days and did not get enough time for proper vegetative growth and tillering and so were not half as productive as the indicas under Indian conditions nor did they exhibit any of the virtues for which they were famous in Japan. Therefore the limited success of the first two japonica × indica hybridization projects was natural as the very premise of the project of transferring the high yield potential and response to fertilizer of japonicas was not apparent in them under Indian conditions. Besides the character of response to high fertility is an interaction of environment and genotype and when the environment was changed the interaction also gave different or negative results. The chances of getting hybrid recombinants with the desirable attributes of both the parents from such a wide genetic scrambling were a slender as getting highly productive hybrids as transgressive segregants from any other inter or intra racial crosses

involving ordinary or poor yielding parents.

It was obvious that the short photoperiod and tropical conditions of the Indian plains transformed the entire physiology of growth development and productivity of japonicas which therefore could not provide productive recombinants in a Mendelian proportion. The ecological specialization to divergent situations had caused genetic incompatibility between the races and the japonica × indica hybrids were seen to have a very high degree (even to 99%) of spikelet sterility in the segregating populations. This is an interesting instance of interaction between genotype and environment ruining the genetic potential for productivity in crop plants themselves or in their hybrid derivatives.

In Japan during the rice season the days are longer and there is a higher level of solar radiation that in tropical countries. In tropical region of India the day length is fairly constant during the crop season but with low solar radiation due to the overcast sky of the monsoon period. Where the long duration crops are raised though the days are bright there is a shortening in day length after the autumn equinox contributing to a reduction in the availability of per day solar radiation. This is one of the significant differences between the rice growing environments of tropical and temperate regions.

As indicated earlier CRRI has been exploring the possibility of direct introductions of exotic types from leading rice producing countries like Japan Taiwan etc. Some of the Japanese varieties when tried under 90 kg N and 35kg P2O5 per ha were found promising (though on par or inferior to local varieties in yield) especially Norin 17 Norin 18 and Zuiho . The Taiwanese introduction Hsunchu was found not as productive as the local or Japanese types. The subsequent introduction of intermediate types from Taiwan proved successful in many parts of the country like Taichung 65 in Karnataka Taichung (Native) 1 in Bihar Tainan 3 and Kaohsiung 18 in Kerala and Hsunchu in U.P. almost setting the stage for the next phase in Indian rice breeding.

Period of inter racial hybridization between semi dwarf Taiwanese types/derivatives and indicas

The development of Taichung (Native) 1 from the semidwarf mutant Dee geo woo gen was major event in rice research in Asia and particularly for India T(N) 1 recorded a productivity which was considered impossible in the tropics before. It was felt then that through extensive cultivation of non lodging semidwarf hybrids rice production could be substantially increased in a short time as in wheat. Enunciation of the plant type concept from an elaboration of the morphology in terms of the physiological efficiency of the semidwarfs stimulated breeding activity throughout most of South Asia and especially India which operated its most intensive rice breeding programmes since 1965 under the All India Co ordinated Rice Improvement Project (AICRIP). Initially the aim was to identify semidwarf varieties that would yield well from Kanyakumari to Kashmir so as to make the seed multiplication and distribution system effective. Padma and Jaya were the first varieties that emerged from this programme. Subsequently varieties were released by Central Variety Release Committee and by the different state agencies. The list of released varieties is given in Appendix I. The numerical superiority of state releases stresses the importance of regional adaptation in rice varieties. Most of these varieties have a yield potential of 3 5 tonnes/ha.

The most significant aspect of this period is the prolific release of hybrid varieties. During this phase 123 varieties were released in twelve years compared to the 51 hybrid varieties released during the four decades prior to 1965. This surge in hybrid releases was facilitated when semidwarf plant habit became one of the easily identifiable selection criteria for breeders.

The plant type or semidwarf varieties with the genetic architecture for physiological efficiency of grain production have been found to be superior to the tall traditional varieties in both kharif and rabi seasons but more so in the rabi season. The following table illustrates the superior response of semidwarf varieties to nitrogen inputs for grain production in comparison to the traditional varieties during rabi season when the

cultivation is under controlled irrigation and ample solar radiation.

As with japonica × indica hybridization the inter racial hybridization programme with Taiwanese varieties or derivatives also ran into difficulties. It was unfortunately reported in the early phase of the semidwarf period that through adoption of semidwarf varieties with improved management practices the production problem could be solved as was done in wheat. But rice being cultivated during the monsoon when no other cereal could be grown in heavy rainfall areas normally faced problems of adaptation to specific ecology and the newly introduced semidwarf types were found unsuitable in a variety of stress situations such as water logging salinity drought low solar radiation due to clouded atmospheric condition etc. when these semidwarf varieties were cultivated under high fertility conditions they were found susceptible to most of the pests and diseases of rice. Continuous and intensive cultivation of these semidwarfs caused disease and pest epidemics which gave premonitions of famine or ruin as in Bihar Andhra Pradesh Kerala Indonesia and elsewhere. These facts again stress the importance of adaptability in monsoon rice varieties to the tracts in which they are to be grown. It is well known that monsoon fosters most of the pests and diseases of rice and high levels of fertilizer inputs aggravate their intensity. In such a situation it is unwise to advocate varieties of identical genetical constitution over wide tracts. Genetic diversity is still the best insurance against disease and pest epidemics as is illustrated by the Indonesian and Kerala catastrophes.

Table 2. Grain yields of semidwarf and local types in kharif and rabi under different nitrogen levels

The concern with disease and pest epidemics has intensified efforts for incorporation of multiple resistance by which is meant resistance to more than one disease or pest in the varieties to be developed. Many of the traditional indicas have been found to be the major donors for disease and pest resistance.

Thus having implicitly accepted the production superiority of the semidwarfs and widely popularized them we have to embark on breeding plant type varieties with tolerance to physiological stresses like drought water logging saline tolerance cold tolerance resistance to diseases and pests and good cooking and eating qualities rather to transfer the desirable traits of the local varieties to the plant type background. The major efforts made in these directions are summarized below.

Breeding upland rices with tolerance to drought

In monsoon dependent rice cultivation uplands with rainfall of 700 1100 mm get exposed to moisture stress periodically due to breaks in monsoon lasting for different periods of a week to ten days of erratic distribution of rainfall. Such areas constitute about a sixth of the world s rice acreage and third of the kharif rice area in India and it is necessary to stabilize yields from such lands to keep up the upward trend in rice production.

Uplands are defined as those lands which are not bunded and wherein water is not therefore impounded during cultivation. Upland rice cultivation entirely depends on rainfall and it is a way of harvesting rain by adopting varieties of suitable duration according to the rainfall pattern.

Four kinds of situations are possible for such a kind of rice cultivation

Rains adequate or assured during vegetative and reproductive phases

Rains inadequate or unreliable during vegetative phase but adequate during reproductive phase

Rains adequate during vegetative phase but inadequate during reproductive phase

Rains inadequate during both vegetative and reproductive phase

The crux of the problem in upland breeding (exposed to moisture stress) as in items and is to find out suitable donors with drought tolerance during the vegetative and reproductive phases as under situation in item rice cultivation is not possible and in item there is no problem of moisture stress.

As there are uplands in all the rice growing states many local varieties suited to such conditions have been identified. Through screening a number of varieties with varying degree of drought tolerance have been

identified (e.g. Mtu. 17 Mettasannavari from Andhra Pradesh Ch. 45 from Bihar Sathi 34 36 from Gujarat Ptb. 28 Ptb. 29 Ptb. 30 from Kerala B 76 from Orissa Lalnakanda 41 from Punjab Tkm.l from Tamil Nadu and N. 22 and Sudha from Uttar Pradesh.

Among these it was found that Lalnakanda 41 Ch. 45 and N. 22 have drought tolerance at the vegetative phase while Mtu. 17 showed drought tolerance even at the reproductive phase.

The first attempt recorded to breed varieties with drought tolerance was in Tamil Nadu during the mid fifties and a drought tolerant variety Co. 31 was released. Kerala also reported some drought tolerant breeding lines from the cross Krasnodar × Kattamodan Culture No. 356 especially.

With the introduction of Taichung (Native) 1 during 1965 efforts were made to transfer drought tolerance to semidwarf hybrids and Bala from the cross N. 22 × T (N) 1 was the first high yielding variety with drought tolerance that was released in the country. As Bala was hard threshing efforts were made to identify lines with easy threshing and good grain qualities. CR. 113 CR. 115 CR. 141 and CR. 143 had many lines with better threshability and grain qualities than Bala . One line viz. CR. 141 192 from the cross (N. 22/ T(N) 1 × T. 90 IR. 8) had been named Kiran in Bihar. Hybrids more productive and tolerant to drought than any of the parents had been identified in the cross CR. 125 (Lalnakanda 41 ×Mtu. 17) × T(N) 1.

International Rice Research Institute (IRRI) geneticists have standardized the testing procedure for drought tolerance of upland rices and have made considerable progress by evolving a large number of promising cultures suited for uplands. Many of these are tested in most rice growing countries including India through the International Rice Testing Programme (IRTP). As the upland rice problems are faced by every rice growing state in India a good number of cultures have been generated by states using local donors and at present many are under trial in the AICRIP testing programme.

Efforts were also made at Central Rice Research Institute (CRRI) to evolve varieties with drought tolerance through induced mutation in traditional varieties. Considerable success was achieved through this approach and many mutants with higher yield potential and drought tolerance than the parents had been identified in Ch. 45 and Mtu. 17 . Mutant Number 2 and 12 of Mtu. 17 had been in district trials in Meghalaya and Manipur. Of special significance is Mtu. 17 Mutant No. 4 which showed very high tolerance to drought even during the flowering phase.

Another mutant from CR. 113 designated CRM. 13 3241 is possibly the earliest induced productive major cereal in the world maturing in seventy days when direct seeded under a temperature regime of over 25°C. This mutant yields about 1½ 2 tonnes/ha normally but with good management has shown potential up to 5 tonnes/ha. In many State Farms under the Department of Agriculture of Orissa Government it had recorded yields 2½ 3½ tonnes/ha. By relying on the earliness of this variety known or predictable drought spells can be avoided or there is a possibility to raise another rice crop after the drought or flood ravages and the resumption of normal monsoon. This variety is to be named shortly by the Orissa Department of Agriculture. In Assam it is found to be promising as pre flood kharif variety (March June) suited for direct seeded condition where it could be grown with the rains received during March June. In Tripura it has been found to be useful in Tillo lands (low mounds). This mutant is under extensive trial in West Bengal. Arunachal Pradesh and Madhya Pradesh.

Breeding for water logged and lowland conditions

Kharif is the main rice crop or season for India extending from June to December practically coinciding with the onset of the south west monsoon and complete recession of north east monsoon. Of the total 38.9 million hectares under rice in India about 20 million ha or 50% of the area are under lowland where there is standing water of varying depths depending on the topography of the land for varying periods. The lowlying areas can be classified into

Water logged area (ill drained conditions)
Flooded areas and
Deep water areas.
The water logged lowlands can be grouped into four categories depending on the depth of standing water and the approximate area under each according to the type of cultivation is shown in the following table. The above classification is mainly based on the toposequence of rice fields. With the onset of monsoon medium lands have shallow rainfed conditions but water gets accumulated later at the peak of monsoon. So in the high rainfall zones medium duration photosensitive varieties are grown in such lands. Where the rainfall is low photosensitive varieties which flower in 100 110 days are preferred. The intermediate lowlands constitute about half of the water logged areas and photosensitive varieties are grown in such lands. In the semi deep and deep water areas there is stagnation of water with the onset of heavy rains (normally from mid July onwards) and there is no way to drain off inundated water. Under such situations only broadcasting with the onset of monsoon is the usual practice.
Table 3. Distribution of water logged areas according to type of cultivation and photosensitivity in million hectares

Soils Their Classification and Agro Chemical Characteristics

The soils on which rice is grown are so extraordinarily varied that there is hardly any type of soil on which it cannot be grown with some degree of success. It is however necessary that the deficiencies of the various soils are identified and made up to increase their productivity.

Classification and Distribution

The soils on which rice is grown in India and their classification
The major soil groups producing rice are Riverine alluvium red yellow red loamy hill and submontane tarai laterite coastal alluvium red sandy or gravelly patches of mixed red and black medium and shallow black soils.
The soils can generally be classified for purposes of rice cultivation in India into
Alluvial soils (Haplaquents Ustifluvents Udifluvents Haplustalfs Ustochrepts)
Calcareous alluvial soils (Calciorthids)
Coastal and deltaic alluvium (Propsualfs)
Red soils (Paleustalfs Rhodustalfs Haplustalfs)
Red and yellow soils (Haplustults Ochraqults Rhodustalfs)
Lateritic soils (Plinthaqults Plinthustults Plinthudults Oxisols)
Black soils (Ustochrepts Uatropepts Pellusterts Chromusterts Pelluderts).
Mixed red and black soils (association of Alfisols and Vertisols)
Grey brown soils (Calciorthids)
Brown hill soils (Palchumults)
Submontane soils (Hapludalfs)
Terai soils (Haplaquolls)
Desert soils (Lithic Entisols Psamments Calciorthids)
Saline alkali soils (Salorthids Salargids and Natrargids) and
Peaty and saline peaty soils (Histosols).
Table 2. Ranges of moisture index and the mean annual temperature in the various climatic zones as used by the Co ordinated Agronomic Experiments Scheme

Table 3. Characteristics of the agroclimatic regions of India

For a comprehensive and meaningful development of research programmes on a regional basis the Indian Council of Agricultural Research has identified eight agro climatic regions in the country and these regions also represent the typical rice growing regions of the country. The agro climatic regions encompassing the different states with soils rainfall temperature etc. which are significant from the point of view of rice cultivation are given in Table 1. This broad division into general agro climatic regions is suited for general agricultural purposes. The soils are also subdivided into agro climatic regions based on the degree of wetness as measured by moisture index which is the excess of precipitation over the potential evapotranspiration expressed as a percentage of the potential evapotranspiration divided into 8 classes designated one to eight with increasing wetness and with each one of them again divided into subclasses A B C D and E which are in an ascending order of coolness based on the mean average temperature. The ranges for the various classes are shown in Table 2. This classification as used by the Co ordinated Agronomic Experiments Scheme might be very useful for determining the cumulative effect of climate on soil characteristics but for its direct effect on rice growth the regions were divided into ten climatic zones by Ghose Ghatge and Subrahmanyan not only depending on the rainfall but also on the critical temperature in the cold months the duration of the dry periods relative humidity etc. as described for the individual states in the last section of this chapter. The characteristics of these zones are shown in Table 3.

Distribution of various kinds of soils in India

The state wise area under rice is given in Table 4. The area occupied by rice in West Bengal and Bihar is nearly the same followed by Orissa Madhya Pradesh Uttar Pradesh Andhra Pradesh Tamil Nadu Assam Maharashtra and Karnataka. These states put together account for more than 90 per cent of the total rice producing area. They also constitute the traditionally rice growing areas in the country. The rest of the states have however limited areas under the rice crop.

The humid western Himalayan region. This region comprises submontane soils hill soils and terai soils in the states of Jammu and Kashmir Himachal Pradesh and the Kumaon and Garhwal divisions of Uttar Pradesh.

The soils that are found in the rice growing tract of Jammu and Kashmir are formed from the alluvium brought by the major rivers Chenab Ravi Tawi and their tributaries. They occur mostly in the Jammu and Kathua districts. They vary in depth are light in texture and their pH ranges from 6.5 to 8.7 they are high in organic matter nitrogen and K2O but are deficient in phosphorus.

The submontane soils include the valley floor and the karewa soils which occur in the Anantnagh Baramulla and Srinagar districts. The valley floor has been constituted by the alluvium deposited by the Jhelum and the Indus. They are silty loam to clay loam and are neutral to alkaline (pH 5.4 8.5).

The karewa soils are somewhat eroded and formed from the deposits which are of lacustrine nature. Their texture is heavy their contents of nitrogen and organic matter are moderate to high and their total P and K ranges from 0.09 0.3 and 0.1 to 0.2 per cent respectively.

The hill soils occur in Uttar Pradesh in the districts of Almora Chamoli Pithorgarh Uttar Kashi and Dehra Dun. They are shallow with fragments of rock occurring within a few centimeters at higher elevations but about three meters in valleys and lower depressions. They are derived from biotite schists and phyllitic materials under moist conditions. The soils groups described by Mukherji and Das fall under the categories of red loam brown forest soil meadow soil and podzolic soil.

The terai soil occurs as a narrow strip from the north west to the extreme north east. The soil remains saturated throughout the year because of sufficient precipitation and high ground water table. They have been formed from the transported materials laid down by different rivers originating from the Himalayas. They are productive and respond to fertilizers. They are classified as Molisols in soil taxonomy.

In Himachal Pradesh the hill soils are formed over a variety of parent rocks comprising sandstones gray micaceous sandstones and shales in the sub Himalayan region where they are located. The soils are loam to silty loam and medium to high in organic matter total nitrogen phosphorus and potash. They are poor in available nutrients. The cation exchange capacity is low to medium.

The humid Bengal Assam basin and the humid eastern Himalayan region and the Bay islands. For convenience these two regions are dealt with together. The altitude of the rice growing areas ranges from a few metres in Sundarbans in West Bengal to about 1660 metres in the north eastern part of the Himalayas in the Mizoram State and up to more than 2 000 metres in Arunachal Pradesh.

The crop is often grown on flat lands to facilitate the supply of water needs. It is grown successfully over a wide range of slopes ranging from nearly level to very steep (podu or thum) cultivation in hilly areas. One of the main limiting factors is the availability of water.

Owing to the adaptability of the rice crop to soils having a wide range of characteristics it is not possible to categorize a particular soil group as rice soil or assess its best use as rice land.

The major groups of soils listed in the table for the two regions included riverine alluvium the terai soils red loamy sandy or gravelly red yellow and laterite soils. Some of the important soil series cultivated for rice in West Bengal extracted from the Soil Survey Reports are Canning Kharbona Jagdishpur Sasanga Hanrgra Totpara and Banpara. They are placed in Entisol Inceptisol and Alfisol in soil taxonomy.

The alluvial soils deposited by the rivers mostly occupy the major part of the wetland rice soils thus contributing the largest share to rice production in the country. They are derived from the deposition mainly as silt deposited by the numerous tributaries of the Ganges and the Brahmaputra systems. The different weathering products of the Himalayas are deposited during the course of their flow through the plains.

In the wetlands the water table is high the drainage is poor and the entire profile remains in a reduced state. Mottled horizons are common and the accumulation of calcium carbonate in the lower horizons is also observed in soils. The flooded condition of paddy soils brings about the movement of iron and manganese compounds from the upper layers and their precipitation in the reduced zone of the lower horizon.

In West Bengal the Rarh region which comprises portion of Murshidabad Bankura the whole of Burdwan and the western half of Midnapore are classified under old alluvium. According to Mukerjee et al. and Digar the textures vary from sandy loams to heavy clays with a hard pan.

The laterite and lateritic soils are found between the Damodar River and the Bhagirathi River interspersed with basaltic and granitic hills. They may be classified into two groups. The first group consists of soils of Midnapore Bankura Burdwan and Birbhum. In these soils the ratio of SiO_2 Al_2O_3 is quite high and because of chemical weathering followed by considerable leaching the soils are deficient in N P_2O_5 and K_2O. They respond to N and P fertilization. At some places buried laterites are also observed at considerable depths underlain by alluvium. These soils give better response to P_2O_5 and the yield of rice is significantly increased by the application of P_2O_5 rather than by that of N.

The red soils of Birbhum Bankura Burdwan and West Dinajpur sometimes misclassified as laterites are transported from the hills of Chhotanagpur Plateau. They are acidic poor in Ca N and available P. They are highly leached and respond to N and P.

The coastal soils in the districts of 24 Parganas and Midnapore after reclamation are producing good crop of rice. They are also rich in plant nutrients. The terai soils in the Jalpaiguri and Cooch Behar districts lying at the foot of the Himalayas are of raw humus type sandy and gray to black.

Soils in the Assam Valley are acidic specially the old alluvial soils whereas the new alluvium is slightly acidic to neutral and in some cases slightly alkaline. The soils are high in available P and K and moderate in organic matter and nitrogen.

The lateritic soils occur in the north eastern mountainous upland areas of Assam. Drainage in the uplands

is good. The groundwater laterites are poorly drained. In some parts of West Bengal by the augmentation of irrigation sources from groundwater reserves through the sinking of tube wells rice is grown in low medium and upland situations. Though rice is adapted to a wide range of soils as mentioned earlier the type of soils suitable for it mainly depends upon the conditions under which the crop is grown rather than upon the nature of the soil.

By the increase in demands for more areas to be brought under the rice crop the conservation of moisture during certain periods becomes necessary owing to insufficient irrigation water. Therefore effective soil depth and suitable texture are very important.

In wetland cultivation soil structure is of little significance but good soil structure ensures better water transmission and moisture preservation for the dryland crop.

The rice crop is better grown mostly in acidic soils whose pH ranges from 5.5 to 6.5. It is successfully grown in saline soils of Sudarabans in the Gangetic delta.

The sub humid Sutlej Ganga alluvial plains

This region experiences low winter temperature and the usual practice are to take a single crop of rice between May June and September October.

The major groups of soil growing rice in the region are calcareous alluvial riverine alluvial saline alkaline red yellow loam red sandy or gravelly and mixed red and black. The alluvial soils owe their origin from the materials brought and deposited by the great rivers from the mountains. They are rich in potash and calcium but are deficient in organic matter nitrogen and phosphorus. The older alluvium is generally deficient in phosphorus lime and organic matter whereas the recent alluvium is well supplied with nutrients because of fresh accumulation of river silt. The soils are placed in Entisol Inceptizon and Alfisol categories.

In the irrigated tracts of the Punjab state the soils are light textured and alkaline. Organic matter and nitrogen are low.

In Uttar Pradesh the alluvial soils occupy nearly 60 per cent of the area in the east west south and central parts of the state. They have developed from the alluvium deposited by the Ganga and the Yamuna and their tributaries. The soils can be broadly classified under (1) light textured alluvium of the west and north west (2) alluvium in the centre possessing intermediate textures and (3) alluvium in the north east derived from the calcareous parent material.

Saline and karail soils occur all along the Ganga river on the left side in the districts of Meerut Aligarh Bulandshar Manipuri Etah Kanpur Fatehpur Allahabad Lucknow Pratapgarh and Sultanpur. The parent materials are alluvial deposits in the riverine areas and finely washed materials in the lower depressions. The soils are highly alkaline indurated and have hard pan which obstructs the downward movement of water.

The karail soils are black finer in texture and occur in the lower basin of Ganga. They occur in the districts of Allahabad Varanasi Ghazipur and Balia. They are formed from the black alluvial deposits transported by the Yamuna from central India.

The Ganga divides Bihar into two halves north and south. The alluvium north of the Ganga has texture varying from sandy loam to clay loam and the pH is neutral to alkaline. Alkaline soils are generally found where the lime content is high. The alluvium south of the Ganga comprising the districts of Patna Ganga and parts of Shahabad is gray to black and light loam to heavy clay. Lime is less and soil pH is slightly alkaline changing to the acidic range in the southern extremity. The middle part which lies in a depression gets flooded during the monsoon. The available K_2O and P_2O_5 are high.

The red soils occur in the districts of Ranchi Hazaribagh Santal Parganas Singhbhum and Manbhum. They are acidic (pH 5.0 6.8) and contain higher and soluble Fe_2O_3 than Al_2O_3. They are rich in available K_2O but are low in P_2O_5.

Seed Rice and Seed Production

The wide use of newly released varieties and proper seed production from breeder and foundation seed to the growers seed stock on the farm are essential for high level rice production with minimum input. New and superior varieties however can make their contribution to practical agriculture only if the seed reaches the farmer in varietally pure state in adequate quantities in an undamaged condition free of weed seed and at a reasonable price.

The general purpose of seed production is to increase those old and new varieties which are superior to standard varieties for commercial distribution. The production of seed rice consists of growing the primary seed called foundation seed and then increasing this seed in sufficient quantities to meet the request of the practical farmer for his seed stock supplies. To produce high quality seed a grower must have a superior seed source of a well adapted variety. Formerly each farm would obtain a certain amount of such seed and multiply it to establish its own seed stock on the farm. But today modern harvesting and processing methods bulk drying and storage have increased the possibility of seed mixing. This led to the need for sources of pure seed. As a result the seed certification program now in effect in this county is an important part of rice production.

Sources of Pure Seed

Production of primary seed is carried out by institution for rice research and their experimental stations and farms. They produce foundation seed (super elite and elite) and multiply promising varieties for release to the growers. Production of farm seed stock is done largely by the commercial grower who breeds foundation seed through three generations the third of which is sown for commercial grain output.

Classes of Seed

The classes of seed termed breeder foundation and certified seed can be described as follows.

Breeder seed is seed directly controlled by the plant breeding institution and is the source of select seed handled at selected nurseries for the production of seed of the certified classes.

Foundation seed is the progeny of breeder or select seed handled at seed increase nurseries to maintain specific genetic purity and identity. Foundation seed is usually the first year increase from breeder seed. It is produced on fields that have not grown another variety or a lower class of the same variety during the 2 previous years. The distribution of foundation seed to growers usually is handled through specialized seed production farms and/or stations under a breeding center that increase this seed to the commercial growers as a certified class seed. For new varieties or for old varieties in short supply specified amounts of seed may be increased or reduced depending on demand.

Certified seed is the progeny of breeder and more so that foundation seed is handled so as to maintain a satisfactory level of genetic purity and identity. It is produced in riceland areas specifically allotted for seed increase purposes. The production and certification of seed is not a part of the breeding program.

The super elite and elite seed is distributed to growers to be increased to quantities sufficient to maintain a seed stock necessary to satisfy the grower s needs. Usually the third year increase from certified or foundation seed is used for commercial grain production. Thus seed of a commercially established variety is renewed once in three years. For the production of the various classes of certified seed it is necessary to have clean land and to prevent mixtures in seeding harvesting and processing. The careful tending of all fields to remove undesirable weeds other crop and off type plants may increase the production costs but is very essential.

Seed Rice Culture

Varietally pure high quality seed in a viable condition can be obtained only through the proper use of the

whole spectrum of agronomic practices. This includes adequate seedbed preparation crops grown preparatory to seeding rice the use of high quality seed optimum dates and methods of seeding adequate fertilization and finally proper mechanical treatments (threshing cleaning and grading). Practical experience has indicated that seed rice grown in good soil that receives the best fertilization and cultivation treatments is usually larger in size than seed of the same variety grown in poor soil and inadequately cultivated. The higher the level of cultivation the slower the process of varietal deterioration under commercial farming. Strict observance of the seed production cultivation requirements usually results in seed with high varietal and field qualities which will be preserved well in the 5th or even 6th generation. Any retreat from the established seed rice cultural requirements may bring about a rapid deterioration in the quality of even the first year seed. This will undoubtedly reduce the grain output of table rice in the area. Usually the fields where rice will be grown for seed are treated much better than the commercial rice paddies to benefit the rice grower with seed rice of high standard. To avoid mixing each variety is sown with a separate clean seeder. The results of rice research and advanced practice indicate that perennial grasses cultivated fallows and new lands developed for rice are good for seed rice production. The land should be thoroughly worked to a fine tilth and adequately fertilized. Saline lands are considered inadequate for seed production and should be avoided. The irrigation and drainage facilities should be operable and in good shape and the land levelled to allow rapid flooding and draining if necessary.

The best time to sow rice for seed is when the soil temperature at a depth of 3 5 cm is 14 to 16°C which for most rice growing areas occurs in late April and early May.

To obtain a high germination rate the seed usually kept cooled during storage in the winter period is aerated and warmed up either in grain bins or grain driers and treated with granosan M 2 3 weeks before seeding.

The rate of seeding depends on the variety and may vary from 4.5 million to 6 million viable seeds per hectare. Where the elite seed is being increased for commercial release the rate of seeding is reduced to 4 5 million viable seeds per hectare. Good results can be obtained by drilling 3 million viable seeds per hectare in rows spaced at 30 cm. This method has proved effective for rapid multiplication of new and promising varieties since under such a wide row method of seeding the multiplication coefficient increases enabling the grower to achieve higher yields at a much lower rate of seeding. Under this method a rate of 100 kg viable seeds per hectare gave 7.16 t/ha of seed rice according to the USSR RRI data.

The wide row method of sowing rice for seed provides for a uniform ripening of seeds on the main and lateral panicles improves plant resistance to lodging and increases the productivity of the plant stand. All this in turn reduces the risk of blast disease and produces seed of a higher class. In addition this method allows for easy weeding to maintain varietal purity and identity of seed by removing off type and other crop plants from the field.

The time to sow rice for seed is equally important. Early seeding results in a thinned stand establishment during emergence while with delayed seeding the seed usually fails to fully mature and as a result exhibits poorer germination.

Seed rice plantings require optimum levels of nutrients particularly phosphorus. Excessive applications of nitrogen fertilizers should be avoided because high nitrogen contents delays maturity especially when the weather during the growing period is cool and rainy. In addition high nitrogen weakens the strength of the stem of the rice plant which leads to severe lodging which results in poorly filled grain high spikelet sterility problems at harvest time and germination in the panicle.

Insofar as possible seed fields should be managed so as to minimize lodging and produce satisfactory yields without excessive vegetation growth. This is impossible with high single rates of nitrogen which must be applied in divided or split dressings. In seed fields ammonium sulfate and urea are preferred over all other sources of nitrogen.

Phosphorus fertilizers appear to improve seed quality. Depending on the forecrop and degree of soil salinity phosphorus is applied as basal at rates from 90 to 150 kg P2O5 per hectare before seeding. Potash is also essential for seed fields to facilitate maturity obtain well filled grain and reduce the percentage of empty spikelets. Potassium is usually applied as topdressing during leaf tube formation (the 8 9 leaf stage) at 30 to 60 kg K2O per hectare.

The Control of Red Rice

The uses of specific varieties that differ in maturity grain type processing and cooking qualities of rice grain have increased the possibility of seed mixing. In this respect the production of seed that is varietally pure and free of persistent weed seeds become extremely important. Preventing intermixing throughout the various phases of seed production requires very close attention by the grower. Commercial varieties could become badly mixed with other varieties and infested with weedy strains of rice. These strains are the red rices that reduced grain and milled yield during harvesting and processing.

All the strains of red rice are characterized by severe shattering rapid growth high yield and a tolerance to adverse environments. Red rice produces many tillers (up to 60) and the progeny from one seed may amount to 1500 1600 viable seeds. Usually the grower inadvertently spreads red rice by planting contaminated seed. Because herbicides do not selectively control red rice in the rice crop infestations should be removed from seed rice fields by other methods if one is to avoid deteriorated quality in seed rice and prevent further spreading of the weed. Red rice contaminates not only the seeding material but also the soil. Tests have indicated that without proper weeding the quantity of red rice in the seeding material the following season increases 5 to 10 fold.

To control red rice it is necessary to know the biology of its strains. Control is difficult yet possible through crop rotations weeding operations renewal of seed sources adequate tillage etc. Red rice infestations of soil can be prevented through using land cropped with perennial grasses seeded fallows and new riceland for elite propagation and seed rice fields. Red rice plants that appear in the first year alfalfa crops following rice do not produce seed because they are cut out with each cut of alfalfa for hay.

Red rice seeds shed into the soil remain viable for several years and are able to sprout from a soil depth of 10 cm. Thus the emergence of a red rice seed plowed under in the fall to depths of 2 and 10 cm would be 20 to 10 percent respectively. All plants that emerged would develop well and produce seed.

Flooding or flushing the soil to provoke red rice emergence is an effective means of red rice control. The method is particularly useful in cultivated fallows where a flood is established after the fallow grown crop has been harvested to soak the soil to refusal. The weeds and volunteer rice plants are then killed by disking or working the field over once with a chisel or plow. Besides mechanical eradication of the soil borne red rice use of high quality seed rice that is free of red rice and other weed seeds is an effective way of controlling repeated infestations.

Red rice infestation increases without regular rogueing of seed fields or when rice follows rice continuously. Infestation will also increase if the grower relies on his own seed stock for several seasons or if the seeding material is badly mixed.

Seed rice fields should be rogued several times during the last part of the growing season to eliminate not only the red rice plants but also the mixed varieties or rogues. The first rogueing is done at tasseling when the panicles of the early rices are visible. The second rogueing is initiated when the seed rice variety has fully developed and the rogues can be checked for the absence or presence of awns and colouration of the panicles. All awned plants are then removed from the seed fields growing awnless varieties of rice and conversely all the awnless plants are removed from the fields growing awned varieties.

Length and diameter grading of seed rice has been extremely useful in removing the larger diameter red rice grains from the seed of long grain varieties. The use of such graders is important in controlling red rice.

In the medium and short grain varieties the only means of red rice control is the use of seed and land which is free of red rice because no method of separation has as yet been devised. The propagation of seed containing red rice soon results in a wild infestation of the soil with red rice strains and further complicates the maintenance of pure seed.

Field inspection of seed rice fields by the Seed Certifying Agency is carried out 5 to 6 days before harvest time to establish the varietal purity and identity of seed rice and to note the degree of infestation with red rice diseases and pests. Where required one additional rogueing may be recommended. Field inspection together with laboratory analyses of seed samples are used for further seed certification. In order for the rice to be eligible for certification the seed rice has to satisfy specific requirements and standards which are available from an official certifying agency. In general these requirements deal with application procedures field and harvest inspections post harvest seed movement seed processing and sampling. All rice growing areas use these standards as the minimum requirements for seed rice.

The Time and Method of Harvesting Seed Rice

The time and method of harvesting seed rice are both important as they influence seed quality. The practice of water management in seed crops is equally important. Drying the fields for harvesting requires the close attention of the grower. Care should be taken when drying a field that the water recedes gradually e.g. at a rate of 1 cm per day. Day to day observation has to be carried out over soil which is drying in areas where rice seed is not dormant and able to swell and germinate in the panicle. If this is the case the depth of water in the rice paddy should be lowered immediately to a minimum and in low lying areas withdrawn completely. To be of high quality seed rice must be harvested at the proper stage of maturity. If the seed crop is cut when immature field yields are reduced and the breakage in threshing is excessive because of the light and chalky kernels. If the seed crop is left in the field until overripe the kernels may check.

The difference in moisture between the inside and the outside of the kernel is said to be the cause of checking or shattering of the grain. When too much moisture is removed due to high temperatures stresses and strains occur in the kernel which result in the microcracking of kernels. The checking of rice depends also on the shape of the grain the degree of maturity the variety and growing conditions but the moisture content still remains the decisive factor. Insofar as the checking of rice is not only the result of the outside (weather) factors but also of the mechanical impact it receives during threshing cleaning artificial drying and grading it is best to employ a method of harvesting that will result in seed with minimum damage percentage. Two staged threshing from the windrow is the preferred method during harvesting seed rice to reduce mechanical damage. The combine threshes about 80 to 85 percent of the grain for seed during the first pass. What is left is threshed during the second round. The USSR RRI tests confirmed by practical observations of growers have indicated that the least losses occur with double stage threshing in which the speed of the thresher cylinder during the first pass (peg tooth cylinder 550 rpm and raspbar cylinder 750 780 rpm) is slower than during the second pass (700 and 1 000 rpm respectively).

Harvesting should not be started until 90 to 95 percent of the grain in the panicle are fully mature. This is established by taking an average sample. Seed rice should be harvested within the shortest time possible and with a minimum interruption between cutting and threshing. The normal procedure is to cut rice let it stay in the windrow for 3 to 5 days to dry and then thresh it from the windrow. Leaving the windrows in the field is unadvisable because of adverse weather factors that may cause the grain to check and lower its quality. Where the two staged harvest method is used for different varieties threshing should by all means be done with thoroughly cleaned combines. To keep varieties segregated use is also made of direct combining where the rice plants are not very badly lodged and the grain yields do not exceed 5 t/ha. In such cases the drying of the grain can be promoted by applying such chemical desiccants as magnesium

sulfate which has proved useful in seed fields in testes conducted in various rice areas about the country. Spraying magnesium chlorate at 25 kg/ha hastens the drying of the grain and straw by 10 to 12 days. This practice prevents lodging reduces by 10 to 15 percent the checking of kernels and permits direct combining. No grower however should use a desiccating material on the maturing seed crop until he has checked its legal status with reference to chemical residue tolerances.

Rice Culture

Rice in the Soviet Union is an artificially irrigated lowland crop seeded directly onto the check. Nursery transplanting is not practiced.

Modern cultures of rice in this country rely on the policy of ever increasing rice production based on the use of engineered rice systems mechanization fertilization and the latest advances in agricultural sciences and practical rice farming.

Each of the country s rice producing areas has incorporated practices of growing and harvesting rice which assure high yields (6 7 t/ha) of good quality paddy rice.

Crop Rotations

In most rice growing farms crops are rotated because under continuous cropping with rice the soil becomes depleted in fertility and organic matter. The resulting deterioration of the physical condition of the rice soil makes cultivation difficult and the soil becomes infested with weeds and diseases that reduce the yield and quality of the rice grain.

Proper choice and establishment of a rotation program is very important for maintaining high and stable production controlling weeds and red rice increasing the irrigation water and land use efficiency as well as the use of farming machinery and labour. Rice rotations help maintain and improve soil tilth and productivity between rice crops provide nutrious forage for livestock on the rice farms and increase the total agricultural output per hectare of riceland. The preferred system of cropping for any farm depends on the soil type local climatic conditions and economic considerations. In any case both the riceland and rice grower should benefit from crops rotated with rice. Rotational crops are selected so as to help eradicate weeds reduce populations of injurious pests control diseases and lower production costs.

Although the biology of rice makes it superior to other crops in that it responds well to repeated or continuous cropping rice in this country is rotated with other crops for the reasons discussed earlier. Rice rotations are also feasible because the increase in rice yields despite a smaller proportion of cropland in rice each year due to rotation is sufficient to maintain or even increase the total rice production on rice farms. A high and stable yield of rice under continuous cropping can be however obtained only with heavy application of commercial fertilizers. The USSR Rice Research Institute has reported that the 27 year average yield of rice grown in a six year rotation was by 1.73 t/ha more than when rice was grown continuously. Rotating rice with other crops is 1.5 times more economical than maintaining a continuous rice culture. In establishing a cropping system a four year rotation of rice gave 0.45 t/ha or 10 percent more rice than the first yield. The yields of rice declined 0.47 t/ha within the same period under continuous cropping. In rotation experiments in the USSR Far East the yield of rice in a seven year rotation system was found to be 1.5 times that of rice under continuous cropping. Similar results were reported from the Uzbek SSR Rice Research Institute.

Continuous planting of lands to rice leads to heavy infestation of riceland with the rice culture related weeds to the detriment of the soil s physical condition and depletion of its fertility.

The beneficial effect of crop rotation on the rice yields can be attributed to many factors. First rotations enrich the plow line soil layer in organic matter and eliminate aquatic and other injurious weeds. Rotations facilitate oxidation of the chemically reduced nutrients improve porosity reduce the bulk mass by improving

soil texture (less amount of particles smaller than 0.25 mm). They are also helpful in controlling insects and diseases and providing better opportunities for surface levelling through timely operations. On commercial rice farms rotations ensure comparatively high and stable grain yields.

Rice rotations in this country were first used in the old Kuban delta land which were formerly overgrown with boggy reed vegetation. An 8000 ha area had been developed for rice and six and seven year rotation systems were tried on its low productive overmoist and partly salinized soils. In the years 1971 75 average yields on the rice farms

Table 1. Rotation vs Continuous Cropping (the Kuban area)

Rice rotations have come into use also in the new Kuban delta ricelands to benefit the rice growers with 5.5 t/ha and more rice which is 1 1.5 tons more than the average yields on the neighbouring farms where rotations are not yet customary.

Cropping systems or rotations have been used by many rice farms in other rice producing areas of the Soviet Union just to demonstrate that crop rotation is essential to ensure rice yields of about 6.0 t/ha or even more.

Cropped Land Structure

Under a rotation program it is sought to use a maximum of cropland in rice following crops that are proven the best predecessors or forecrops. Such crops for rice are those that improve soil productivity and help the rice grower obtain good returns from a hectare of cropland. For this purpose the irrigated ricelands should for the greater part of the year be preferably used for raising high yielding crops. Since livestock has been extensively developed in most rice growing areas such crops are grown basically for feed purposes. In this way crop rotations are a useful tool in matching up the cultivation of rice and livestock raising.

Usually the rice systems are designed and engineered for a particular rotation pattern. The choice for a cropping pattern is therefore very important the determining factors being agricultural specialization soil type water and drainage conditions in the locality and the agronomic function of the rotation system. The idea of crop rotation implies that crops be periodically changed e.g. flooded rice is followed by a dryland crop. Such alternation of crops is mutually beneficial because it helps eliminate the deteriorative effect on the rice soil of extensive floods by allowing the soil to dry out when it is in a dryland crop. The cropping systems should be selected so that the proportion and the order of crops in the cropland are easily adaptable to different economic situations without readjusting the irrigation facility layout. Research and farming have proved that long time rotations such as the seven eight and nine year rotational programs are most suitable in this respect.

Of the numerous long time cropping systems the eight year rotation with perennial grasses and seeded or cultivated fallows is preferred as the most flexible one. Under such a cropping pattern 62.5 percent of the land is used for rice this proportion being easily increased to 75 percent when necessary. The rice soil benefits from this system in receiving a double amount of organic matter first from turning under the perennial grasses then from the annuals. In addition the eight year rotation system provides better opportunities for the basic land forming and levelling operations in each field check. In most rice producing areas this cropping pattern has been the basis for design and construction of new riceland developments. Also other scientifically grounded cropping systems involving rice for various periods have been in use on rice farms of other locations in the Kuban delta lands.

The Krasnodar Territory

Many rice farms use the eight year rotation with the following orders and frequency of crops first two years perennial grasses (alfalfa clover) third to fifth year rice sixth year seeded fallow followed by two annual crops of rice (with 62.5 percent of the land being used for rice 25 percent for perennial grasses and 12.5 percent for cultivated fallows under the system). About one fourth of the cropland in the Kuban delta is in a

seven year rotation first and second year. Perennial grasses (alfalfa clover) third to fifth year rice sixth year cultivated fallow and seventh year rice or first year cultivated fallow second and third year rice fourth year other grain crops overseeded with perennials fifth year grasses and sixth and seventh year rice (with 57.1 per cent of land in rice under the system). Where the long time rotation is impracticable but the agronomic practices are advanced and labour and power resources are plentiful the rice growers choose to use short term cropping systems such as the three year rotation first year seeded fallow and second and third year rice (with 66.7 percent of the cropland in rice) and four year rotation first year cultivated fallows and three years in rice i.e. three fourth of the time the land being used for rice under the system.

The Don Piver and Cis Caspian Lowland

Depending on local conditions and economic considerations rice growers here may choose between six seven and eight year rotation systems.

In a six year rotation the frequency of crops is first and second year perennial grasses third and fourth year rice fifth year seeded fallow (spring grain crops) and sixth year rice (with 50 percent of land in rice 33.4 percent in perennial grasses and 16.6 percent in seeded fallows). Also row crops and pulses may be fallow grown in some localities.

The seven year cropping systems recommended for these areas are similar to those used by the rice growing farms in the Northern Caucasus. The fallow grown crops may vary with the locality from winter wheat pulses or spring barley in eight year rotations (with 62.5 percent of land in rice) to vegetable crops in seven year rotations.

The USSR Far East

In the Monsoon climate of the Far East the cropping patterns vary. The eight year rotation may have a different order of crops depending on the depth of snow pack in the winter. Thus in localities where snow cover is permanent an eight year rotation may be first to third year rice half of the fourth year green manure crop the other half maintenance of the irrigation facilities fifth and sixth year rice seventh year barley or oats over cropped with clover eighth year clover (with 62.5 percent of the land in rice). Where snow is marginal the order and frequency of crops is first to third year rice half of the fourth year green manure crops the other half maintenance of the irrigation facilities fifth and sixth year rice seventh year cultivated fallow and eighth year forage crop the percentage of land in rice being the same. In other localities recommendations are for a seven year rotation as follows first year grain crop second year feed crop third and fourth year rice fifth year green manure crop sixth and seventh year rice (with 57 percent of cropland being used for rice). A six year rotation allows for one year in grain crop two years in rice one year in soybeans for green manure and two years in rice (with 66.7 percent of land in rice). The practice for newly developed ricelands has been a four year rotation consisting of three years in rice followed by half a year of green manure crops and the other half used for maintenance of the irrigation facilities (with 75 percent of land in rice under the cropping system).

The Ukraine Uzbekistan and Southern Kazakhstan

With allowance for the local traditions and climate the cropping patterns are essentially the same but may vary in length from four to nine years also in the order of crops and in the proportion of land in rice which may range from 43 to 66.7 percent. Whatever the order and frequency of crops in rotations rice growers have to follow the general tendency of crops in rotations rice growers have to follow the general tendency of allotting a maximum and economically feasible proportion of the land to rice as a staple culture and grow catch crops on it in between rice croppings.

Intensified Cropping Systems

Because of the high cost of land development for rice one way to ensure good returns from a hectare of

irrigated land is by putting the riceland to intensive agricultural use. Considering the limited geography of rice in this country another way is to extend the acreage for rice in a rotation in addition to increasing the yield of rice through improved agronomy and superior varieties. Research on rotating rice with other crops has proved it possible to repeat rice cropping (up to four years) in the same field. Obtaining high and stable yields under such a system of cropping requires periodic incorporation into the soil of organic matter optimum applications of fertilizer good water management sufficient treatment of the field with herbicides and adequate agronomic practices. Rotational experiments conducted by the USSR Rice Research Institute indicate that the yield and gross output of rice can be increased through using rotations making better use of perennial grasses increasing to more than three years the length of repeated cropping of rice after perennial grasses and through growing catch crops between rice croppings.

The eight year rotation system developed by the researchers for the Kuban delta ricelands can be considered as intensified rotation with 75 percent of land in rice. The coefficient of land use under this system increases from 1.25 to 1.75 due to growing catch crops and better use of perennial grasses.

Time 2. Rotation of Rice with and without Catch Crops

Forecrops

The growth of agricultural plants and cultural methods used for soil cultivation and particularly application of water and fertilizers cause various changes in the physical chemical and biological properties of the soil. This in turn affects the growth and development of crops that are grown on the same field the following years by increasing or decreasing their yield. The knowledge of how the individual species or groups of plants may influence the crop grown in alternate years is very important for appraising these plants or species as the forecrops for setting the proper order and frequency of crops in a rotation.

It has been proved by many tests and practical rice farming that perennial legumes fallow grown annual legumes and green manure crops leguminous gramineous mixtures and cruciferous plants and catch crops grown for seed and green manure are best for growing in rotations ahead of rice.

For other rice growing areas the crops preceeding rice in rotations are essentialy the same. In addition sweet or sour clover crimson clover mixed with berseem or Egyptian clover are sown in Kazakhstan Uzbekistan and Turkmenia. The Sudan grass and spring wheat are grown in fallow fields and as catch crops in the Ukraine and Kazakhstan while corn (maize) sorghum joughara mixed with mung beans sweet clover and vetch oats mixtures are sown in Kazakhstan Uzbekistan and Tajikistan.

The rice soil benefits much from alfalfa and clover if grown for two years. The grasses improve the physical condition of the soil increase the content of organic matter and soil productivity. Perennials facilitate the conversion of almost insoluble phosphorus compounds into readily soluble ones whose quantities tend to increase with the age of grasses. With a two year old grass cover the soil has a maximum of available phosphates. In rice rotations the total yield of alfalfa hay (four cuts) may reach 8 10 t/ha with the cost of one feed unit much lower than that of annual legumes. High yield of alfalfa in rice rotations is due to good agronomic practices including check flood irrigation or sprinkling and fertilizer applications.

The beneficial effect of alfalfa on the rice soils is higher when the two year old grass is left over winter to be turned under the following spring after the first cut of hay. In this case it gives additional 25 30 t/ha of green matter (5 tons on dry matter basis) before the field is sown to rice. The method of turning under alfalfa in spring has become customary with the rice farms in the Kuban rice areas ensuring stable yield of good quality hay in addition to 5 t/ha of early of mid season rice each year and increasing the organic matter in the soil in the form of roots and other plants debris. The higher the yield of perennial grasses grown ahead of rice in rotation the higher their beneficial effect on the rice soils and consequently on rice yield. Grasses therefore must be given the best agronomic care including seasonal irrigation and fertilizer treatments combined with soil slitting to produce highest yields of hay already in the first year.

Modern agronomic practices and adequate timing of optimum nitrogen and phosphorus fertilizer applications make it possible to maintain and sometimes increase the yield of rice grown three years continuously after grasses.

The yields of rice in an eight year rotation depending on the forecrop were as follows (the data of the USSR RRI).

Practical rice growing in the Kuban ricelands showed that alfalfa grown for two years ahead of rice and plowed under in the spring before seeding rice gives assured 5.0 5.5 t/ha of rice grain and with fertilizers up to 6.0 7.0 t/ha. Similar yields of rice in grassland broken at fall are attainable only with the application of 90 100 kg/ha of nitrogen fertilizers and phosphates (P2O5).

Fallowing

The chief aim of fallowing fields is controlling weeds check land leveling and reshaping and maintaining water structures. But because the land development for rice is costly it is unwise to allow the land to lie idle and hence pure fallowing is not encouraged. The fallow fields are therefore seeded or cultivated which permits the chief aim of fallowing to be achieved plus the fallow grown crops additionally gathered.

Seeded or cultivated fallows are fields used for growing various agricultural crops which when ripe leave fields free from plants soon after harvest for the land leveling operation. such crops in the Northern Caucasus are winter wheat mixed with winter peas or vetch grown for hay or green chop spring vetch mixed with oats winter and spring peas mixed with oats or barley and winter barley. The fallow grown crop in the Lower Volga rice farms is mostly winter rye mixed with vetch for green chop. In the Far East ricelands such crop is soybeans.

The use of mineral fertilizers for the fallow grown winter crops is mandatory in all the rice producing areas. The rates vary with the area and soil productivity. The soils in the Kuban delta lands require 120 kg N in addition to 90 kg P2O5 per hectare applied as basal fertilizer during the fall plowing for grains in pulses. Nitrogen applications are split into 90 kg/ha at seedbed preparation and 30 kg/ha as an early dressing.

For early spring crops such as barley wheat peas and oats mixed with vetch and peas the fertilizers are applied at seedbed preparation or at harrowing.

The yields of vetch and oat mixtures sown in fallows for hay are about 5 t/ha winter wheat and peas produce by early spring 3 to 4 t/ha and winter peas sown in autumn produce up to 3 t/ha of nutritious green matter.

All these crops are however susceptible to excess moisture. Crop failures may result from too much water held in checks after heavy rainfall and cloudburst unless adequate drainage is provided.

The choice and composition of fallow grown crops relies on the economic considerations availability of seeds and the possibility for annual land levelling in the checks which is a key operation for obtaining high rice yields the following season. In selecting and allotting lands to the accompanying crops of rice rotation and fallows the physical condition of the flooded soils is particularly important. Alfalfa barley corn and peas do not grow well where drainage is poor and the water table high. Their yields are low from excess water and poor thin stands. Adequate drainage is therefore the only remedy from water logging and inundation of rice fields and the adjacent areas which are in dryland crops. Of the crops which can tolerate high ground waters crimson clover berseem (Egyptian clover) and mung beans are the most tolerant.

Benefits to the staple rice culture from cultivated fallows in the rotation are high only with good weed control proper grading and levelling of land and increased organic matter in the soil due to fallow grown annual legumes and grasses. The intensive use of land through seeded fallows makes possible double cropping of riceland so that two crops are harvested the same year provided all operations are expertly timed.

Catch crops

Double cropping implies growing catch crops for use either at fall or early next spring as feed or green manure the same year after the main fallow grown crop is harvested field levelled and given the semi fallow tillage. Growing catch crops is also important for improving soil productivity and rice yield. The name catch crop applies to crops grown the same year following the staple crop and intended for feed or green manure. They are also known as stubble crops. The term is also applicable to crops sown in the spring into the cover crops to keep growing still for some time after the cover crop is harvested. Such crops are also called the companion or nurse crops the name applies to crops sown in summer or in the fall following the staple crop and harvested for feed purpose the following spring before a main crop is sown and known as the wintering crop and also to crops sown on fields free from the previous crop harvested early in season for green chop sillage or hay and sometimes called the postharvest crops which elsewhere can be grown as the main crop.

The agricultural plants selected to be grown as catch crops should be high yielding and early maturing recommended for this or that area and well adapted to heavy and periodically flooded soils. Among such crops are pulses (winter and spring vetch and peavine) winter rye winter wheat barley oats spring rapeseed all sown in pure or mixed stands.

In the Northern Caucasus and the Lower Volga rice areas the fallow grown catch crops are sown in the summer or fall and thus are called summer crops. The same crops to be grown in rice fields are sown as winter crops. In the rice producing areas of the USSR Far East the catch crop is soybeans (when grown in fallows it is for green manure although soybeans can be grown for grain).

Winter rye is good as a catch crop. Some of its winter varieties are winter hardy and shoot out well early in the spring at low temperatures (close to zero) producing fairly good yield of nutritious green matter so valuable early in the spring for its vitamins.

In many rice growing areas of this country and particularly in the Cis Caspian Lowland rotational crops are grown in saline soils. In such cases adequate drainage and importation are necessary to avoid water logging inundation and salinization of the land in accompanying crops and grasses that are adjacent to rice fields on the one hand and make the best use of the rotation on the other. Of the accompanying crops peas oats and corn are less tolerant to salts than are rye wheat sorghum and particularly alfalfa. Gourds and melons tolerate better high concentrations of salts. Soils moisture content is an important regulator of the degree of salt tolerance of the rotational crops. The higher the moisture content the more tolerant the plants to salinity during their early development.

To provide high and stable yield each rotational crop in a rice cropping system should be grown under optimum agronomic conditions. It has been established that the rice yield to a large extent depends on the productivity of the preceeding crops. Thus yield or rice following one year alfalfa depending on its crop of hay was as follows

Good timing of catch crops is also important in a rice rotation. It is advisable that in the rice fields which are planned the following season for catch crops rices are early maturing and sown in the current year as early as possible. In that way the crop of rice is ready to harvest much early giving the grower time enough to prepare the land for catch crops of the following year.

Land Preparation

Tilling soil for rice is not much the same as tilling for other cereals and dryland crops. Its principal aim in rice production is to obtain high yields of rice through improving the rice soil and taking advantage of its potential productivity.

While the dryland crops require soil nutrients in the oxidized form the rice plant benefits more when the nutrients are chemically reduced or deoxidized. The dryland crops require that the capillary noncapillary porosity ratio (determined by the water stable soil structure and soil moisture brought to capillary capacity)

be optimum while this soil parameter for rice is practically for rice is practically unimportant.
Nutrition of the rice plant is in large measure assured by inundation during part of all of the growing period. Flooding is very much essential for optimum grain yields that are why the ideal soil types for rice production are those that conserve water. Most rice soils often referred to as heavy soils because of their high clay and silt content present special soil management problem that are overcome through soil cultivation practices intended also to help make the best use of the natural soil potential. These measures include tillage and seedbed preparation maintenance of organic matter and soil texture drainage for successful mechanized rice operations cultivation of other crops in rotation with rice fertilizer application use of green manures and weed control.
Soil tillage practices vary from place to place depending on soil type climatic conditions crop that preceedes rice in rotation physical condition of the soil character and degree of field infestation herbicides used and other factors. Tillage in rice production pursues many purposes which are generally aimed at
Forming a sufficiently deep and biologically active plowline layer by working the field several times over with various types of plow
Creating conditions in the plow line that help immobilize soil nutrients i.e. regulate oxidation and reduction through loosening drying and aerating of soil
Wetting the rice fields that are to be sown at early dates and to a greater depth so as to establish the moisture content sufficient to bring about emergence of rice seedlings without additional flush irrigation
Preparing the riceland with a soil structure that will ensure a uniform coverage and germination of seeds good stand establishment and further development of the plant during growing season
Controlling weeds pests and diseases of rice and other rotational crops by plowing in the fall one time over with a chisel and a second time in the spring with a mouldboard
Precise levelling of the field surface (to within ± 5 cm from the median plane of the rice check surface) to maintain desired depth of flood water in the field and to drain as rapidly as required
Covering organic and mineral fertilizers at desired depths
Preparing a suitable seedbed for rice.

Harvest and Post Harvest Operations

The harvesting of mature rice and post harvesting operations are important aspects of rice culture. Rice crops usually mature later in the season than other grain crops. The time to harvest rice therefore varies from early September in the European USSR to mid September in the Far East. For the best results harvesting should continue for no more than 20 25 days. Delaying or extending the time of harvesting increases losses reduces both yield and grain quality and does not provide enough time to adequately prepare the land for next season s crops.
Factors that determine the duration of the harvest are the time and date of seeding the maturity period of the rice variety the level of infestation soil and drainage conditions in the rice fields and the weather before and during harvesting.

Draining for the Harvest

Draining at the proper time before harvesting is required to sufficiently dry the soil to use the heavy rice harvesting machinery. It is however equally important to maintain the water in the rice field long enough to permit the rice crop to reach proper maturity.
When to drain depends on the soil type drainage facilities and weather conditions in any given season. Some soils dry quickly others slowly. Rice growers soon familiarize themselves with the time to dry their soil and soon learn to judge when the best time is to drain the fields for harvesting without letting the rice crop suffer from a lack of soil moisture. In a year with a typical amount of heat and rainfall the date when

rice will be ready to cut can be estimated by observing the date of flowering and initiation of heading. Rice normally requires 40 to 50 days from flowering to maturity.

The flow of water into the checks is usually reduced by the time rice reaches the soft dough (milky) stage and is discontinued altogether when the rice matures to the hard dough (waxy) stage so that the water will recede slowly at a rate of 1 1.5 cm per day. Where the soils are saline the fields are drained. The level of groundwater should preferably be maintained low through proper drainage to avoid waterlogging the checks. Less time is required to dry the soil where drainage furrows have been opened in the spring. In fields without drainage furrows pools of water are likely to appear. In such cases the water is either pumped out or removed through hand made furrows.

Usually riceland may be drained when the rice crop has fully headed and the panicles have turned down and ripened in the upper parts. This stage normally occurs about 2 3 weeks before the rice crop is ready to harvest.

Water intake should be discontinued progressively beginning with the low lying checks that are usually downstream from the headwork then successively with the checks at higher elevations. This results in a simultaneous and uniform drying of the paddies in each large check. By the time the rice crop is ready to cut the soil should be dry enough to support the harvesting machines and equipment.

Premature drying of the field checks will delay the filling of grain so the rice crop harvested too early will have a greater quantity of immature empty and poor quality grains and will produce a smaller yield of head rice at milling. On the other hand it is equally important not to miss the time of maturity. When rice stands too long in the field losses are increased due to lodging premature germination in the panicle and shattering.

Pre Harvest Chemical Drying

The pre harvest application of chemical desiccants is a frequently used practice to speed the drying of rice in the field before harvest. Of all the known materials applied as sprays a 60% magnesium chlorate water solution has proved the most effective when it is used at 25 kg to 150 liters water per hectare. After treatment with this desiccant about 2 3 percent grain moisture and 4 6 percent leaf moisture is removed daily. Within 4 to 6 days as soon the grain moisture content is brought down from within 20 27 to 15 16 percent the rice can be harvested.

The aerial application of desiccants gives best results when carried out on clear bright days early in the morning or afternoon. Average diurnal temperatures should be about 9 10°C with a maximum wind velocity of 4 m/s. Very good results are obtained if there is no rain for about 6 to 8 h after spraying. The application of chemical desiccants at optimum dates (when 85 90 percent of kernels are fully mature) increases the grain yield improves the seed quality and reduces both labour and harvest time by 10 to 15 days. Rice treated with desiccants is usually harvested by direct combining.

Chemical materials used as desiccants should be considered poisonous so no grower should use a desiccating chemical on the maturing rice crop until he has checked its legal status with reference to chemical residue tolerances. When used with caution however desiccants can give good results without the traditional after effect such as a drop in milling quality kernel dislocation and an off flavour that may occasionally be imparted to the rice.

A new method of speeding up the drying of rice has recently been proposed by Professor E.P. Aleshin [8] and has proven effective in improving harvesting conditions and grain quality and in reducing harvest losses. It relies entirely on a solution of water soluble phosphorus fertilizers plus small amounts of 2 4 D amine salt which is applied as a top dressing on rice in the milky stage of ripening.

Pre Harvest Operations

After the irrigation water has been withheld and the soil is sufficiently dry the rice around the check s

border is cut with either a self propelled crawler mounted reaper a combined harvester thresher or a crawler mounted swather. This is done 2 3 days before the all out harvesting of the rice begins in the fields enabling more time for the soil to dry out and the rice to mature as well as eliminating the risk that the harvesting machines will run onto hydraulic structure invisible to the operator.

Square shaped rice paddies and large checks are divided into strips 50 to 70 m wide by cutting swaths from one end of the field to the other. Two cross swaths are cut from both sides of the field to provide a 6 to 10 m wide headland for the harvesting equipment. This increases the efficiency of the harvesting machines by about 15 to 20 percent reducing hand labour and field losses.

The time to harvest food and seed rice can be determined by observing the date when 85 and 95 percent of the grains in the respective panicles are fully mature. If the crop is left in the field until it is overripe the kernels may check. This will cause breakage during combining and milling and a reduction in the yield of whole kernels (head rice). Biological yield losses from harvesting delayed by three days amount to about 0.2 t./ha. The losses rice to 0.5 1.0 t/ha when harvesting is delayed by 10 to 15 days. It follows that the prime time for cutting the rice crop should not be missed by the grower. Any delay will result in reduced yield due to shattering during hot dry days and slow threshing if the weather is humid and cool.

The time to harvest depends largely on the weather. The mid season varieties of rice (Kuban 3) which are sown about the same date should be harvested within 8 to 10 days and the late rices (Krasnodarsky 424) within 10 12 days. It has been established that standing rice does not hold its maximum yield for long. In the Kuban river riceland for instance rice keeps its optimal grain yield (to within ± 5 percent of the maximum) only 8 to 10 days.

Harvesting Rice

Most rice in the Soviet Union is harvested mechanically either with self propelled combine harvesters or with a tractor drawn header or swather which threshes from the windrow. Harvesting by hand may be resorted to only on very small acreages when the weather is rainy and the use of harvesting machines is impractical.

Direct combining or single phase harvesting and separate or two phase harvesting are the two major methods to harvest rice in this country.

Over 80 percent of the total rice acreage in the USSR is harvested by the two phase method. Essentially this is cutting the rice with a swather or windrower and threshing it from the windrow with a pickup combine when the grain is adequately dry. The rice is then dried artificially before it is stored or milled. Careful adjustment of the reaping machine and the thresher leads to grain of a high milling quality and market value.

The two phase method permits rice to be cut at earlier dates followed by threshing from the windrow 3 5 days after. This results in grain with much less moisture content thus reducing the cost of artificial drying. If the rice crop is left in the windrow too long the grain may check (crack) increasing breakage during threshing and milling and markedly reducing the yield of head rice and quality of seed rice. It is therefore better to thresh from the windrow at the proper time and avoid large intervals between cutting and threshing.

Direct combining or combine harvesting is more efficient and economic in that it provides grain of the highest milling quality and considerably reduces fields losses. It is more effective over the two phase method particularly when the weather at harvest time is unstable because it permits rice to be removed from the field in one operation with no danger of weather damage. Hopefully with improved combines along with a wider use of desiccants grain driers cleaning facilities and less lodging rice varieties that produce less vegetative growth direct combining will find a wider application in the near future.

Already in some rice growing areas self propelled rice combines provide the major means of harvesting

rice.
With either method obtaining a control yield of threshed grain by cutting and threshing 2 swaths in 2 3 representative (typical) field checks or rice paddies has become an important practice in all rice producing areas. Practical observation confirmed by growers results indicate that the operator is the most important factor in preventing high combine losses. Therefore control threshing is usually done first by highly skilled combine operators who determine for the other operators where to adjust the thresher device in the combines and the cutter head in the swathers and reapers.
With the common two phase harvest method rice is cut with a tractor mounted side delivery windrower or reaper. Front mounted swathers having two active cutter bars are good for cutting badly lodged rice. A header or windrower is also suitable in such cases as it delivers uniform windrows from 4.5 to 5 m wide swaths. Such windrows dry quickly. Self propelled headers or swathers with the knife divider removed and the reel adjusted to the rear shield of the frame can also be successfully used to cut rice crops that are badly lodged. These adjustments reduce the number of cut out panicles lower losses by reel shattering and improve the operating condition of the reel and the delivery chain. The cam action reel should be adjusted 200 250 mm frontwise relative to the cutter so that the rake just touches the plant stem at 2/3 of its height from the base. The reel is adjusted in level with the cutter bar to cut lodged rice below the point of bending i.e. 50 70 mm from the top so that the reel rake then only cleans the knife and pushes the cut plants onto the delivery chain. The reel speed should always exceed the ground speed of the swather. This effects proper reaping at 15 20 cm from the ground surface and minimizes field losses. The height at which the rice is cut is very important because the proper amount of straw serves as a cushion to the grain during threshing resulting in a lower cylinder loss and less breakage.
Rice in a paddy or large check may be cut either by the strip or by the continuous method. With the first method each swather or combine works a strip of rice crop 50 70 m wide. It starts on one of its longer sides makes a 90 deg turn at the corner and an idle run along the shorter side of the strip to turn again and cut rice along the other longer side in the opposite direction working clockwise from the check s field margin towards the center line of the strip.
Strip harvesting is good for harvesting field checks where the swather can pass over the levees from one rice paddy to another. The efficiency of the harvesting equipment is 15 20 percent higher as the idle run distance on the head land is considerably reduced. The method is usually used for cutting badly lodged rice or under extremely muddy conditions when turns are difficult to make due to large clods on the headland.
The continuous method is effective where soil is more dry and rice is not lodging. The method requires no headland as the harvester cuts the rice going counterclockwise along the check and makes a turn to the right (270° loop) each time it reaches a field corner.
Usually several harvesters form a group that completes harvesting a field check within 3 4 days (15 20 hectares per each swather). The group method permits the rice crop to be quickly cut and threshed with a pickup combine as soon as the windrows are sufficiently dry. Where the harvest time is late August and early September and the days are warm and dry threshing from the windrow is normally begun 3 5 days after cutting. Where the harvest time is late September and early October the interval between cutting and threshing may be longer. Threshing from the windrow may not begin until the grain (not the stem) moisture content reaches 16 to 20 percent. Field observations confirmed by grower s reports indicate that if rice is left in windrows until over dried this results in grain of poor quality creating heavy losses during threshing and milling.
The threshing operation in a field check 15 to 20 ha in size is also done by a group of 4 to 5 pickup combines. They are assisted by tractor drawn or self propelled grain carts which haul the threshed grain from the combine to the field side trucks who in turn haul the grain further to the driers or the elevator.

With an average efficiency of 3 4 ha per combine such a harvesting team may complete a field check in 2 3 days. In both methods total field losses can be minimized and grain quality improved by threshing the rice straw with unthreshed grain a second time. Double threshing requires that 85 to 95 percent of the grain the threshed during the first threshing round while the remaining grain is threshed during the second round with a pickup combine harvester. The combine thresher should be adjusted so that no threshed grain will go into the new windrow as the straw leaves the combine. The windrows should be uniform in shape and not too large so that they do not crowd the feed. The more straw is fed the higher the cylinder losses particularly if the grain s moisture content is excessively high. Because the rice kernel is susceptible to cracking the cylinders should be run at a slower speed than usual for small grain crops.

To obtain maximum grain yields it is necessary for the cylinder and the concave to be in good condition and for the concaves and other parts of the combine to be properly adjusted. The major combine losses are attributed to the cutter bar cylinder rack and cleaning shoe. Other losses may be due to overloading or improper machine adjustment or a combination of the two. Overloading as a result of excessive ground speed is usually a major cause for heavy loss in all types and sizes of combines. Modern combines can be adjusted to do a good job of threshing with a minimum of shelling and cracking of the grain.

With a lath reel pickup grain losses are about two times less than with the pegged reel version of the pickup attachment. For this reason the lath reel pickup is preferable to the pegged reel pickup. High losses of unthreshed grain usually result from either improper cylinder (drum) or concave adjustments or both. Losses of threshed grain may also come from poor separation in the straw wakers and cleaning shoe. Several tests should be made with each machine to determine the effect of adjusting or changing the ground speed. Cylinder speed should be varied with the rice varieties and the grain straw moisture content.

Table 1. Combine Cylinder Speed for the First Round of Threshing rpm

Reducing the cylinder speed helps minimize shelling and cracking of the grain but may increase the loss of unthreshed grain. For the second round of threshing the speed of the fan and cylinders should be greater than the rated one by 20 percent.

Rice harvesting machines include various tractor driven swathers and reapers self propelled headers and windrowers and self propelled combined thresher harvesters equipped with crawler tracks half tracks or tyres. In rainy season wide mud cleats may be bolted onto the tracks to increase support to the harvester. Other tractors and combines are equipped with tyres with mud lugs or cages so that they can be operated on the sloping levees and under extremely muddy conditions.

The rice farming machines usually operate by either the traction or floating principle. By the first the tracks or tyres penetrate the muddy tilth to reach the hard pan on which they find a firm support for traction. By the second principle machines have to move by flotation acquiring support on the top muddy soil with the help of cage wheel or track extensions (extendable lugs). Ricegrowers would very much appreciate special self propelled rice combines equipped with the rice special tyre . Some self propelled harvesters are equipped with large bins or hoppers for collecting the threshed grain. The hoppers are emptied by mechanically augering the rice into self propelled bankouts or tractor driven carts that take the rice to trucks which wait alongside the field. The rice is then hauled to driers or to aeration bins where it is unloaded by use of grain augers or other bulk handling means.

Grain Moisture Content

Because the grain moisture content varies with the time of day the combine threshing parts should be re adjusted several times during the day at 9 10 a.m. and 6 7 p.m. for the wet straw and between 12 and 4 p.m. for the dry straw.

Rice must be of high milling quality to command a premium price and to obtain this high quality and maximum yields rice must be cut at the proper stage of maturity (moisture content).

When the rice crop has reached the proper stage and grain moisture harvesting should proceed quickly because the loss of moisture in standing rice can be very rapid. If rice is harvested at the proper stage the grains are fully mature in the upper portions of the panicle and are in the hard dough stage at the base of the panicle. Observations indicate that maximum yields of head rice were obtained when rice was harvested at moisture content of about 18 to 24 percent and then immediately dried to 13 and 14 percent. Varieties differ as to the range of moisture content at which they yield the best quality milled rice. This range is rather wide varying from 16 to 25 percent for some varieties. Many rice growers determine the moisture content of hand harvested samples of their rice with various types of moisture meters before they begin all out harvesting.

Thus when harvesting for maximum quality a lot of factors must be considered but moisture content of the grain at harvest time is among the most important. Good results may be obtained with the use of chemical desiccants which hasten pre harvest of the crop if applied timely and properly.

Post Harvest Operations

Straw Removal and Use

Post harvest tillage and preparation for the next crop require that the rice fields be cleaned of rice straw and other plant residues. The straw can be removed from the field after it is bailed picked up and stacked off field to be processed for animal feed. Some other suggested uses are as bedding construction material for manurial purposes or as a mulching material for purpose of soil protection. The straw can be removed from the fields either as the harvest proceeds or immediately after the harvest. For soil mulching the straw is simply cut in the rice field with special straw spreaders or choppers and the straw particles are then spread uniformly over the stubble to facilitate plowing under with a disk plow. Some combines are now equipped with straw spreaders that cut up the straw as it leaves the combine. Various other machines such as straw rakes pickup choppers stackers and loaders assisted with special tractor driven straw carts are used to facilitate the operation and haul straw stacks from the fields.

Processing Rice for Storage and Milling

The cleaning and drying of rough rice is very important for safe grain storage. Timely and proper processing of the field run rice usually results in attaining grain of the highest quality and commercial value with lower input per unit volume of rice dried and stored. The post harvest procedures include pre cleaning or scalping drying and grading of the rough rice. Usually the rough rice coming from the field unless the fields are clean contains considerable foreign material such as stems weed seeds and trash. It is therefore advisable to clean it partially with a scalper aspirator machine before putting it into the bin for aeration. In some areas facilities and conditions may require that the rice first be dried. Such drying may require that the rice be passed though the drier several times. Frequently the rice is also aerated between passes to remove foreign matter and light weight immature grains before it is put into storage.

Preliminary cleaning of rough rice can be done on the on farm facilities that should include a fanning mill with a wind aspirator to remove light grains hulls and other light weight foreign material a screen with large perforations to remove any remaining sticks stems lumps and large weed seeds and a finely perforated screen to remove fine broken rice grain small weed seeds and other small particles of foreign material. The pre cleaned rice is then put into bins for aeration.

Aeration

Is the procedure used to cool and ventilate grain during storage to improve quality and prevent spoilage. This can be accomplished by turning the grain at regular intervals by transferring it from one bin to another with a grain loader or grain thrower or by circulating air through the stored grain.

For proper drying moisture must be removed from inside the rice kernel. Drying too fast can result in internal cracking or checking of the kernels. To prevent this drying is usually done in several stage with the

moisture reduced only about 2 percent at each drying. After each stage the rice is tempered in a bin so that the kernel moisture will equilibrate.

Weeds and Their Control

Weeds compete with rice for light nutrients space and water they also adversely affect the microclimate around the plant and harbour diseases and pests. They reduce yields lower the market value of the crop by reducing quality and increase the cost of production harvesting drying and cleaning.

Slightly more than 250 species of plants have been registered as weeds that infest rice fields in the Soviet Union. Of these about 20 species are persistent weeds that infest old ricelands and some 10 12 species are weeds frequently found in crops that are grown in rotation with rice.

Weeds that infest rice fields differ from those that infest dryland and even irrigated crops. They are from the species that thrives best in extremely wet or flooded soil.

Plants that infest rice fields can ecologically be grouped as hydrophylous marshy aquatic and floating weeds and algae.

Hydrophylous weed plants include barnyard grass (Echinochloa contracta Stev. E. phyllopogon Stapf. and E. crus galli L.).

The weeds in this group are common to all rice growing areas and grow equally well in waterlogged soils and fields flooded with shallow water. Prolonged and deep flooding is fatal for the young weed grass.

Barnyard grass is an annual plant and is the most persistent weed in seed rice and food rice plantings. Early in season it is often hard to differentiate between the young rice seedlings and those of the weed grass because of various morphological and biological characters that are quite similar in both species. However the rice leaf is more rigid robust and rough than that of the barnyard grass which has a wider vein in the centre and is a paler green. The stalk in rice is somewhat flat at the base and it is round in barnyard grass.

Table. 1. Young Rice vs Young Barnyard Grass

One barnyard grass plant may produce from 600 to 800 seeds in average rice stands and from 3 000 to 6 000 seeds in thin stands. The heat requirement of barnyard grass is about the same as that of rice. Echinochloa spp. germinates at temperatures not lower than 12°C in very wet or flooded soils. The optimum temperature for germination is from 20 to 25°C. Shed in the soil the weed seed remains viable for 3 years it may germinate and give seedlings in dryland from a depth of 6 cm when the soil is compact and from 12 cm when the soil is loose. It germinates and sprouts seedlings from topsoil covered with a shallow layer of water about 1 3 cm.

Echinochioa contracta Stev. tillers well in rich soils and in thin stands. It can be long awned medium awned and awnless. All three forms of the species are subject to shattering thus infesting rice fields badly. The weight of 1 000 grains varies from 6 7 g to 11 g. The matured seed has no dormancy period and since it sheds in wet gound it germinates rapidly from late September to early October when the soil is sufficiently moist the weather warm and temperatures about 16 18°C. In the spring the seed of the weed sprouts from a soil depth of 1 12 cm as soon as the soil temperature reaches 12 14°C. By late May its germination percentage is about 93 98. The best soil conditions for sprouting are a soil moisture content of about 90 100 percent of the least field capacity and a temperature of 20 to 25°C. In the spring 100 percent of the weed seeds germinate and sprout from a 1 3 cm soil depth 80 percent from a 5 cm depth and 56 percent from a 10 12 cm soil depth in rice fields where a flood about 15 cm deep is maintained. After a year in rice about 20 percent of the seeds within a soil layer from 0 to 20 cm may still be viable. The young grass can stand shallow water but a flood of about 25 cm would be fatal.

Echinochloa phyllopogon Stapf. can be either awned or awnless. The awnless forms shatter more and infest rice soils directly. The awned from are more resistant to shattering and infest rice fields through

uncleaned seed rice. The weed has a well developed root system and produces many tillers. 1 000 grains weigh 4 7 g. The seed is not dormant and germinates rapidly producing vigorous seedlings at excessive soil moisture and soil temperatures of 14 15°C. The young weed grass can stand deep water but floods up to 25 30 cm in hot weather will kill the weed within 5 to 7 days. Morphologically E. phyllopogon is closer to rice than other forms of the species and has about the same maturity period. The seed of the weed buried deep in the soil remains viable up to 5 years and is able to sprout in compact soil up to 10 cm deep. The seed however fails to produce seedlings from a soil layer of 2 cm under submergence but the established seedlings can stand deep water for the rest of the growing period.

Echinochloa crus galli L. can be long awned medium awned or awnless. The long awned forms usually infest fields where rice is cultivated under continuous submergence. The weed can sprout from a soil depth of 3 5 cm in a field with a 10 cm deep water cover but it fails to produce seedlings through a layer of water as high as 15 20 cm.

Because they are ecologically closer to dryland weeds the medium awned and awnless forms normally infest rice fields under rotational irrigation. These forms of barnyard grass mature even earlier than do the early rices and shatter more than other weed grasses. The small sized seed has a period of dormancy. The 1 000 grain weight varies between 1.5 and 2.0 g. Once shed the seed volunteers in early April from a soil depth of 1 cm but not until mid April from a depth of 3 5 cm. In the spring up to the time for seeding rice about 80 percent of barnyard grass seeds present in a soil depth of 1 5 cm will emerge and about 50 percent will sprout in a soil layer between 0 and 20 cm provided that air temperatures are 12 to 23°C and soil moisture accounts for 70 to 85 percent of the least field capacity. When irrigation water is provided from April 16 to May 20 about 28 percent more seeds that survived the winter within the 0 20 cm soil layer will emerge. However about 17 percent of such seeds will still remain within the rice field. Under rotational irrigation water applications for crops other than rice (usually grasses) can during one summer in a dryland crop yield up to 95 percent of barnyard grass plants from the 1 25 cm soil layer. E. crus galli is a viable plant that grows back every time the main crop of grass is cut.

Rice cutgrass (Leersia oryzoides L.) a perennial grass has recently become a problem in Uzbekistan Kazakhstan and in the Northern Caucasus. The weed grass infests primarily rice fields under rotational irrigation and also irrigation ditches. It propagates by seed and other propagules called rhizomes. During its growing period one rice cutgrass plant produces rhizomes up to 1 m long with 12 15 internodes. The winter buds start to grow in the spring when temperatures are from 8 to 12°C. The culm of the plant varies in height from 50 to 150 cm and its leaf is sharply indented on the edges. The inflorescence is an expanded panicle up to 18 cm long that bears many spikelets (from 500 to 700).

Marshy weed plants are largely perennials that infest fields which are continuously in rice as well as low lying fields checks which are waterlogged most of the time. The weeds in this group thrive exclusively or waterlogged and submerged lands and can withstand deep water and prolonged submergence. The weeds propagate by seed and by vegetations. Their propagules are rhizomes tubers or root tubers. These start to grow in the spring at soil temperatures about 10 11°C. Because it seedling usually emerge earlier than those of rice they compete vigorously with each other for the growth essentials.

Common reed (Phragmites communis Trin.) thrives in waterlogged areas and ricelands where table water is high. It propagates vegetatively through its well developed rootstock that penetrates soil to 1.5 m as well as through above ground propagules that creep over the soil surface. The common reed has no special soil requirements and grow well in both saline and good soils.

Bulrush (Boldoschoenus compactus Hoffm.) and clubrush (B. maritimus Palla) are sedge weeds. The stalk is 85 cm tall and triangular at the base. The leaf is long (70 cm) narrow and rough. The mature seed is small and dormant and is shed long before the early rice is harvested. Most of the seeds (up to 50 80 percent) over winter on check surfaces then germinate and produce shoots in the spring when

temperatures stabilize about 20°C and soil moisture approaches field capacity. Seedlings may even grow through a thin sheet of water about 1 2 cm. In the soil the seed remains viable for about 5 8 years. Both forms propagate by seed and by tuber. During one season each tuber lying at a depth of 11 15 cm produces from 10 to 47 new tubers and in a year old grassland up to 11 tubers. Tuberization occurs primarily within the 2 10 cm layer of soil. In old riceland the number of tubers within the depth of the plow line may sometimes be as high as 1 000 2 000 tubers per sq m. Tubers that are buried at a depth of 20 23 cm for more than 9 years lose about 70 75 percent of their viability. Drying and freezing of the soil in old riceland markedly reduces the viability of propagules within the top soil. Drying of the soil (i.e. soil moisture under 14 percent) is fatal to tubers.

Spikerush (Junceilus serotinus Rottd.) is another persistent weed of the sedge family. The triangular culm is about 1 m tall. It propagates by seed and by rootstock. The seed s dormancy and germination rates are about the same as in bulrush seed. Propagation is however usually vegetative through the rootstock. One fruit bearing organ produces up to 47 new cord like rhizomes in one season. The rhizomes are spaced at 3 to 20 cm apart and sit at the end of the old rootstock. Freezing and drying of soil is lethal only to the surface confined rhizomes.

Common cattail also mace reed and narrow leaf cattail are perennial weeds with a thick creeping rootstocks buried at a depth of 5 10 cm. These weeds have a 2 cm and a 0.5 1.0 cm broad leaf respectively. Both weeds propagate by seed and by rootstock. The small sized seeds have a pappus and are grouped into cylindrical inflorescences each containing up to 4 50 000 seeds. The seed germination rate is about 100 percent in the year when the plant flowers. The seed produces shoots at temperatures no lower than 20°C in overwet soils or fields with a thin water layer. Draining of fields and drying of the soil kills the young plants. The weed infests mostly irrigation and drainage ditches and newly developed rice lands it also thrives where cultural practices are poor.

Common water plantain (Alisma plantago aquatica var. maritima L.) is a perennial weed that infests rice fields in the Ukraine Northern Caucasus Kazakhstan and Uzbekistan. Oriental water plantain (A. plantago asiatica) is a weed that causes problems in the Far East rice lands. It is a prolific plant that propagates by seed and by tubers. Its maturity period is shorter than that of rice. The matured seed shatters and thus infests rice soils. One plants is able to produce anywhere from 15 000 20 000 and more achenes with a high seedling vigour. The seed germinates rapidly both in soils with moisture that is close to field capacity and in submerged soils with a floodwater temperature of 15 18°C. From the 1 cm layer of submerged soil water plantain emerges shortly after rice and completes with the rice seedlings for strength and becomes robust until the rice row stand close. The competition is particularly vigorous where the stands of crop are thin. Weed shoots develop from the buds that sit on the propagative tubers and soon appear to form leaves (in June and early July) that float on the floodwater surface shading and suppressing the young rice.

When buried in wet soil water plantain propagules with auxiliary buds can remain viable indefinitely and are able to withstand heavy frosts. Even a mild frost however can kill tubers when they are brought to the surface during soil cultivation. Smoothing underwater check surfaces following land preparation operations during the summer is considered an effective means of controlling water plantain.

Pickerel weed (Monochoria korsakovi Regal et Meack.) is an annual broadleaf weed that can survive in deep water. Pickerel weed usually infests rice fields and irrigation and drainage ditches. It is common in the far eastern rice producing areas and is a major weed where rice is shallowly seeded. Outbreaks of Monochoria have been recently reported in the Northern Caucasus - particularly in the Kuban delta ricelands.

The mature plant is 50 60 cm tall and has a succulent stem with thick broad leaves. It propagates by seed which is enclosed in a ball with a large pericarp. One Monochoria plant produces up to 20 000 seeds. The

mature seed germinates well in a soil with moisture close to field capacity or in flooded soil. The young weed plant usually emerges in rice fields from mid June to early July. The weed is susceptible to shade. A good rice stand will suppress Monochoria in that a large number of the plants will die for lack of daylight. Most of the remaining plants (up to 95 percent) fail to produce inflorescence and therefore do not flower. The weed however thrives in thin stands and then competes vigorously with rice thus reducing grain yields. An efficient means of controlling Monochoria is to sow rice early and deep thus permitting seedlings to be obtained using naturally stored moisture. An additional means of combatting the weed is to level the fallow fields when they are under water.

Arrowhead or duck potato (Sagittaria trifolia L.) is a perennial plant with arrow shaped leaves. It propagates by seed and tuber forming stolons at depths ranging from 6 9 to 15 cm. These are underground shoots bearing about 8 tubers at each end. The tuber has a crown bud from which a seedling can develop earlier than from the seed itself. At soil depths of 20 25 cm the tubers remain viable for about a year or so. Drying of the soils kills tubers while a layer of water stimulates the tuber developing seedling which can survive in deep water and can break surface through depths of up to 50 cm. The small sized seed remains viable for about 5 years.

Acquatic weeds

Acquatic weeds include both the annuals and perennials which can grow and bear fruit while immersed or floating on the water surface. Some of these weeds propagate by seed (chara and naiad) others both vegetatively and by seed (pondweeds). Drying of the soil is harmful to all the weeds under this group. Chara and naiad are annual weed plants 15 20 cm tall that propagate by seed. They infest mostly the irrigation canals and rice field areas around turnouts. Drying of the fields for 2 3 days kills the weeds. Clasping leaf pondweed floating pondweed and common pondweed are perennials that propagate both by seed and vegetatively. The shallow rooted rhizomes are able to easily break from the soil and are dispersed by flowing water. The weeds are unable to tolerate dry conditions and therefore infest primarily irrigation and drainage facilities as well as fields where rice is grown continuously. The economic losses attributable to these weeds are large. They infest waterways thus greatly reducing the water carrying capacity of the delivery canals by raising the water level in the drainage ditches. This in turn causes the water table in the non irrigated downstream lands to rise thus injuring or sometimes killing the dryland crops grown there. Proper choice of rotational crops can effectively control these weeds.

Floating weeds

Thrive in rice fields and drainage and irrigation ditches. This group includes ninebark duckweed or duck s meat horned pondweed and many others. These weeds are mostly annual and propagate by seed.

Algae

Are lower plants several unicellular and multicellular forms of which commonly infest rice fields. When temperatures are high algae of various sizes and shapes rapidly develop colonies in the water (usually in mid May and June). One such algae is diatom which is the first to appear. Others are green algae blue green algae and brown algae. All these algae frequently form scum that deposits a dirty film on the emerging rice seedlings which retards and frequently prevents further growth of the young rice plants. Algae scum is most harmful during emergence of the rice plants.

Weed Control Practices

Effective systems of weed control combine preventive mechanical cultural and chemical methods. Nonchemical methods include several or all of the following practices using weed free seed rice crop rotations seedbed preparation and land levelling selecting the proper methods of seeding and water and fertilizer management. Chemical methods are based on the use of herbicides that effectively control weeds in rice if applied properly and timely.

Nonchemical Weed Control

Weed control practices differ depending on the species and amount of weeds the structure of cropped acreage in the rotation the availability of irrigation water drainage conditions in the rice field and rice varieties.

The nonchemical practices can be preventive mechanical and cultural. Proper combination of some or all of such practices will provide an effective weed control system.

Practices that prevent weed infestations or their spread in clean fields include the use of high quality seed rice that is free of weed seed irrigation with water that is free of weed seeds and other weed propagules and cultivation with clean equipment.

Plowing disking harrowing rotary tilling or combinations of these mechanical methods are used to prepare rice fields seedbed and eliminate young weeds. In new ricelands presowing tillage of fall plowed fields or spring plowing is done several days before seeding to level the check surfaces and make a fine tilth in the top layer (8 10 cm). One of the main goals of all methods of seedbed preparation is to eliminate all weed growth up to the time of seeding. Deep plowing in the fall (up to 20 25 cm) with inversion of the soil layer to turn down the topsoil infested with weed seeds and subsequent tilling in the spring without inversion (subsoiling or chiseling) so as not to bring the seeds to the surface is a good practice to control barnyard grass and other gramineous weeds. The method chosen depends on type of soil soil condition (mellowness) other crops in rotation the method of seeding climate and the kinds of weed present.

Primary cultivation usually provides good conditions for weed seed germination and emergence and subsequent cultivation eliminates young weeds and conserves soil moisture. Old weeds that may survive on incomplete seedbeds are not so easy to control therefore thorough preparation is important.

In the major rice growing areas the old riceland is harrowed late in March or in April to bring up barnyard grass. The rice fields are then disked and harrowed again to eliminate young weeds. If the spring is dry the old rice fields are flushed one or two times to provoke weed emergence 6 to10 days before weed control cultivations. The number of presowing soil cultivations needed to control barnyard grass depends on how compact the topsoil is.

The seeding method influences weed problems. The depth of tillage regardless of implements used should not exceed 5 6 cm in the field where rice is to be drilled and is unlimited in these areas where the rice is broadcast onto the dry ground or in water. Time intervals between weed control cultivations and between seeding the rice and flooding the soil should be minimized. If this condition is satisfied the layer of water will prevent the emergence of the barnyard grass whose seeds are only 2 cm deep in the soil.

Firming the soil with a roller packer is a good way to bring up weed grasses due to the capillary rise of water to the topsoil usually infested with weed seeds. On the average the rate of weed emergence per square meter on ground that has been firmed is twice that on unpacked ground. The young weeds that emerge after soil firming are easily eliminated by proper cultivations. However the barnyard grass that emerges along with the drilled or dry seeded rice is difficult to control by cultural or mechanical methods.

Water seeding reduces the growth of barnyard grass and other weed grasses during rice emergence.

Herbicides are essential for controlling annual grasses that infest dry seeded rice and other weeds that infest water seeded rice such as the aquatic weeds and sedge.

Pest Profile and Integrated Pest Management in Aromatic Rices

Introduction

Diseases and pests attacking normal rice cultivars also attack aromatic rices only their relative importance

may vary. Diseases and pests which are favoured by late maturity (lower temperature) dense crop canopy and/or low nitrogen are more prevalent in aromatic rices because of their long duration and tall stature. Many aromatic rice varieties are in cultivation in their native areas since ages. Their nitrogen requirement is very low. They have become adapted and show less susceptibility to different diseases and pests in their native areas of cultivation. However some of the improved high yielding aromatic rice varieties an highly susceptible to diseases and pests like neck blast sheath rot sheath bight yellow stem borer white backed plant hopper (WBPH) brown plant hopper (BPH) leaf folders etc. Even traditional varieties may suffer severaly once they are cultivated beyond their native areas. There is hardly any disease or pest attack on Tapovan basmati in village Tapovan areas (Tehri Uttaranchal). However same variety was severaly attacked by neck blast and sheath rot when grown in plains. This paper reviews the disease and pest profile and discusses the importance of integrated pests management (IPM) in aromatic rices.

Diseases

Since aromatic rices are grown under both irrigated and rainfed ecosystems which include lowland upland and high altitude ecologies most of the diseases are reported from one or other areas. The most destructive diseases on aromatic rices are neck blast sheath rot sheath blight bacterial blight and brown spot. These and some other less important diseases are discussed in following section

Brown Spot

Helminthosporiosis or brown spot disease of rice caused by Cochliobolus miyabeanus (Ito & Kuribayashi) Drechseler (anamorph Bipolaris oryzae (Breda de Haan) Shoemaker) is one of the most important diseases of the traditional aromatic rice more so under rainfed conditions. Disease appears as small oval or circular dark brown spots on leaves and glumes (Fig. 1). Spots are relatively evenly distributed on the leaf surface. The disease is primarily seedborne however secondary spread is rapid under favourable environment. Disease is aggravated by poor fertility conditions like low nitrogen phosphorus and potassium. Due to lodging problem in tall aromatic rice varieties low dosage of nitrogen is applied. This results in high incidence of brown spot. Proper application of nitrogen particularly in slow release form suppresses disease development. However one must be careful as high N may aggravate lodging problem. Disease can be managed by seed treatment followed by foliar spray of fungicides like mancozeb carboxin bitertanol etc. Application of Si also reduces disease intensity. Biocontrol agents like Bacillus subtilis applied through seed soil or foliar spray have been found to be effective. A number of aromatic rice land races/germplasms have been identified as resistant under natural condition. However among the improved aromatic rice varieties only Pusa Basmati- 1 is reported to be resistant.

Sheath Blight Complex

In rice sheath blight complex three species of Rhizoctonia R. solani (teleomorph Thanetephorus cucumeris) R. oryzae (teleomorph Waitea circinata) and R. oryzae sativae (teleomorph Ceratobasidium oryzae sativae) are involved. Rhizoctonia solani inciting sheath blight is the most widely distributed species on rice. First symptoms are greenish gray spots that develop on leaf sheath near the waterline. The elliptical or oval spots enlarge to 2 to 3 cm and coalesce with each other Figure (1). Disease may spread to upper sheath and occasionally to leaves. Losses may vary depending upon the time of appearance of the disease. Rhizoctonia solani has got very wide host range. However based primarily on the astomosis behaviour it has been subdivided into 13 intra specific groups [an astomosis groups (AGs) and sub groups]. However all the isolates of R. solani obtained from rice belong to AG 1 IA and only isolates from AG 1 IA and AG 1IB are capable of producing typical symptom of rice sheath blight. Isolates from other groups were either non pathogenic or induced hypersensitive/resistant reaction on rice. However rice isolates of R. solani exhibit a wide variation in their morphological and virulence characteristics even if they are obtained from same field. Disease is favoured by high N and P high plant density and dense canopy.

High yielding dwarf broad leaf N and P responsive varieties like Pusa Basmati 1 are particularly susceptible to sheath blight. Nitrogen increases sheath blight essentially via indirect effects increased tissue contacts in the canopy and higher leaf wetness. In addition to dosage time of application of nitrogen also affects sheath blight development. High K disfavours disease.

There is a lack of resistance against sheath blight. However some of the varieties/lines of aromatic rices have shown reasonably good degree of tolerance (U.S. Singh R.K. Singh and G.S. Khush personal observation). Crop rotation if followed properly could be one of the effective methods in keeping the soil population of rice isolates in check. Balanced application of NPK spray of borax and sulphates of Zn Cu and Fe reduce sheath blight incidence. A number of fungicides like propiconazole pencyuron diclonazine flutolanil mancozeb iprodione carbendazim are effective against the disease. New generation compound acibenzolar S methyle is reported to reduce sheath blight severity when applied through soil or as spray on plants by inducing plant defense mechanism. A number of biocontrol agents like Pseudomonas fluorescens Bacillus sp Trichoderma virens or T. harzianum alone or in combination with organic manure (Gliricidia maculata leaves) have been found effective in reducing the sheath blight infection under field conditions. Trichoderma harzianum is an efficient mycoparasite of R. solani. Preliminary studies have shown that rice wheat rotation which is the most popular in northern India does not favour sheath blight development in spite of the fact that wheat is susceptible to rice isolates of R. solani. However summer rice maize or mentha do favour sheath blight.

Blast

Rice blast caused by Magnaporthe grisea is a serious problem in aromatic rices even under low land irrigated system because of the long duration of crop. It is most serious problem in aromatic rises in Iran Pakistan and India. In 1964 neck blast epidemic was experienced in Basmati rices in Punjab province of Pakistan. During 1989 blast epidemic in Basmati in Haryana (India) resulted in loss of Rs. 110 million. Blast epidemic in Kalanamak for two consecutive years 1998 and 1999 resulted in sharp decline in area under this variety in its native belt i.e. districts Siddharthanagar Basti Gorakhpur etc.

Blast has two phases leaf blast and panicle blast. Leaf blast is characterized by elliptical or spindle shaped lesions with whitish gray or greenish centre and brown or purple margins with yellow halo. Panicle blast which is more damaging appears as a dark necrotic lesion covering partially or completely around the panicle base or secondary branches. It may lead to breaking of panicles resulting in few or no grain setting. At the time of grain filling in aromatic rices temperature is comparatively low which favours panicle blast development. Disease is favoured by high nitrogen. Soils with poor silica availability are blast conducive. In most parts of the world population of pathogen is reported to be clonal. However in Himalayan hills population structure of M. grisea exhibits high diversity in rice strains. Some evidence suggest recombination of rice and non rice infecting strains in Indian Himalayas as a cause for this high diversity. In view of this information there is urgent need to analyze variability in M. grisea population affecting late maturing aromatic rices grown in Himalayan foothills. It may have lot of bearing on blast management particularly on resistance breeding.

A number of effective fungicides like carbendazim carpropamid tricyclazole pyroquilone ediphenphos etc. are available against rice blast. In aromatic rices they are being used widely by the farmers. New generation chemicals like tricyclazoles carpropamid etc. are environmentally safe and provide good protection. Rather than being directly fungitoxic these chemicals act as antipenetrants by blocking melanin biosynthesis in appressoria. Some of the biocontrol agents like Pseudomonas fluorescens Bacillus sp. and mixed formulation of Pseudomonas fluorescens + Trichoderma harzianum have been found effective against the disease. Application of silica fertilizers reduces blast incidence. Host resistance is the most effective method for the management of rice blast (Table 1). Unfortunately most of the popular varieties of

aromatic rices are susceptible to neck blast. Nevertheless a wide variation in reaction towards neck blast was noticed in different Indian germplasm/land races of aromatic rices.

Sheath Rot

Sheath rot caused by Sarocladium oryzae (Sawada) W. Gams & Hawksw which was considered only a minor disease till a few years ago has now attained the status of a major disease. It is primarily because of the introduction of some of the high yielding varieties. It might increase further with the popularization of the hybrid varieties. Typical symptoms are oblong to irregular brown to gray lesions on boot leaf sheath near panicle. Lesions may coalesce covering the entire sheath. Disease is highly damaging as it infects boot leaf sheath and under severe condition it may totally inhibit panicle emergence. Burning of the infected stables planting of the tolerant varieties spray of fungicide like carbendazim at tillering and boot leaf stage and biocontrol agents are some of the methods recommended for the disease management. A wide variation was observed in natural incidence of sheath rot in different germplasm/land races of Indian aromatic rices (U.S. Singh. R.K. Singh and G.S. Khush personal observation). Early planted rice crops could escape disease incidence.

False Smut

Like sheath rot false smut caused by Ustilaginoidea virens is another disease which has gained importance only during the last few years with the introduction of some of the high yielding varieties. Infected grains are transformed into yellow greenish or greenish black velvety looking spore balls. Incidence of the disease is likely to increase with the popularization of hybrid varieties. Disease is favoured by high nitrogen. Sanitation practice like manual removal of sclerotia before harvesting proper dose of nitrogen and spray of fungicides like foltaf mancozeb etc. are some of the recommended management practices.

Foot Root

Bakanae or foot rot a seed borne disease is caused by Gibberella fugikuroi (Anamorph Fusarium moniliforme). Infected seedlings/plants are elongated nearly twice the height of the normal plants with thin yellow green leaves. Elongated plants die. Infected plants that survive until maturity bear only partially filled grains or empty panicles. High nitrogen and temperature range of 30 to 35°C favour the disease. This is one of the major diseases in Basmati belts of Haryana (India) and Punjab (India and Pakistan). In 1991 most of the Basmati fields in Punjab province of Pakistan were badly affected by this disease. Outbreaks of this disease were observed in Haryana during 1989 1990 and 1992. Foot rot can be effectively controlled by seed dressing with fungicide like carbendazim.

Stem Rot

Stem rot caused by Magnaporthe salvini (sclerotial stage Sclerotium oryzae is endemic in eastern U.P. Infection starts near the waterline as blackish dark irregular lesions on the outer leaf sheath and gradually enlarges. Eventually fungus penetrates into culm and weakens the stem leading to lodging. The disease is favoured by high nitrogen while K and Si application reduce disease incidence. Application of balanced fertilizer burning of stubble after harvest avoidance of waterlogging for long period and planting of moderately resistant varieties are some of the recommended methods for the disease management. Some of the aromatic rice varieties are reported to be resistant to stem rot.

Narrow Brown Leaf Spot

This disease is caused by Cercospora oryzae. Incidence of the disease has increased in recent past particularly in Bijnore (U.P.) and Dehradun (Uttaranchal). The disease is characterized by small narrow elongated dark brown spots spread uniformly over the leaf surface. Work is in progress to develop disease resistant varieties. Some of the non aromatic resistant varieties like Mahssuri Bhawani IR 26 IR 28 IR 29 and IR 30 may serve as donors.

Bacterial Blight

This disease is caused by bacterium Xanthomonas campestris pv. oryzae (Ishiyama) Dye. Disease may appear both in nursery (Kresek phase) as well as in field. Kresek phase is characterized by wilting of seedlings. In mature plants lesions usually start near the leaf tip or margins or both and extend down the outer edges. Young lesions are pale green to grayish green later turning yellow to gray necrotic. Lesions may extend to entire leaf length (Figure 1). Disease is more serious under irrigated conditions. Bacterial blight is a widely distributed and devastating disease of rice. Some of the aromatic rice cultivars like Pusa Basmati 1 are highly susceptible to bacterial blight. It is favoured by high N. Planting of resistant cultivars is the best method of disease management. A number of resistant varieties are available among non aromatic rices. Among aromatic rices HBC 19 Pakistani Basmati Ghanal and IET 9691 showed resistance to bacterial blight. Proper use of nitrogen and avoidance of shade and water stagnation in field help keeping the diseases in check.

Grain Discolouration

It is characterized by darkening of glumes of spikelets brown to black including rotten glumes. Disease intensity ranges from sporadic discol ouration to discolouration of entire glumes. A number of fungi viz. sarocladium oryzae cochliobolus miyabeanus Alternaria alternata Magnaporthe salvini M. grisea etc. are reported to be involved in grain discolouration. High rainfall at the time of maturity favours development of grain discolouration.

Insect Pests

Insect pests pose serious threat to cultivation of rice in almost all regions of the world where rice is grown. More than 800 insects species have been recorded damaging rice in one way or another although majority of them are of little importance. In a particular area insect pests attacking aromatic rice are the same as those prevalent on non aromatic rices. Nevertheless mainly due to long duration tall stature and dense canopy the aromatic rice cultivars are more susceptible to insect infestation as compared to non aromatic rice due to which the farmers in many traditionally aromatic rice belt have given up its cultivation. In India the aromatic rice is damaged seriously by yellow stem borer Scripophaga incertulas Walker leaf folder Cnaphalocrosis medinalis Guenee white backed plant hopper Sogatella furcifera and brown plant hopper Nilaparvata lugens.

Yellow Stem Borer Scripophaga incertulas (Walker) (Lepidoptera Pyralidae)

The most serious insect pest of Basmati rice in the entire northern Indian belt is yellow stem borer. Studies conducted in Punjab over five years revealed that non protection of Basmati 385 may result in 80 97% white ears in crop due to stem borers. Yellow stem borer epidemic was recorded in Basmati belt of Haryana and Punjab during 1998 where 50% incidence of white head was noticed. The yellow stem borer lays eggs near the tip of leaf blade which are covered with buff coloured hairs derived from anal tuft of female moth. One female moth lays an average of 2 to 3 clusters of egg each containing about 60 to 100 eggs. About a week after hatching the larvae from the leaf sheath bore into the stem and staying in the pith feed on the inner surface of the walls. Such feeding often results in severing of the apical parts of the plants from the base. When this kind of damage occurs during vegetative stage of the plant central leaf does not unfold turns brown and dries off although the lower leaves remain green and healthy. This condition is called dead heart . The affected tillers dry out without bearing panicles. After panicle initiation severing of the growing plant parts from the base result in the drying of the panicles which may not emerge at all and those that have already emerged do not produce grains. This condition is known as white ear head . The borer remain active in the field almost from nursery stage to crop maturity. However they cause more injury to the plant from the middle to later part of the crop growth. It has been observed that among the three stages of crop growth maximum tillering stage registers highest infestation followed by flowering and early

tilering stages. It has also been noted that the variety having more tillers per hill suffer more from yellow stem borer. The economic injury threshold for dead heart and white head are reported to be 5.7 12 and 9.4 14.7% respectively. These values seem to be quite high value aromatic rices. It may be revised as 5 and 3% respectively for dead heart and white head.

Hoppers

Hopper burn caused either by white backed plant hopper (WBPH) or brown plant hopper (BPH) is quite common to aromatic rices. They may result in serious losses. In recent years incidence of green leaf hopper is on increase in Basmati in Uttaranchal Tara.

1. Brown planthopper Nilaparvata lugens (Stal.) (Homoptera Delphacidae)

The nymphs and adults of brown plant hopper suck the phloem sap from the basal portion of the plant which result in yellowing and wilting of plants and finally leading to hopper burn. The eggs of BPH are usually laid in groups in the tissues of the lower part of rice plant mainly in the leaf sheath but at times also in the leaf blades. One female may lay 400 500 eggs which hatch in 7 10 days. In the Basmati belts the population of this insect remains very high in September October.

2. White backed planthopper Sogatella furcifera (Horvath) (Homoptera Delphacidae)

In U.P. and Uttaranchal white backed planthopper is more common than BPH. It lays eggs in masses in the leaf sheath tissues of the plant which hatch in 3 14 days. During the period of feeding variety and stages of crop also affect the symptoms. If the attack is before heading stage lower leaves followed gradually by the upper leaves turn yellow to bronze. There are stunting and reduction in the number of productive tillers. When the damage is in the panicle formation stage the number of grains and panicle length decrease considerably. There is adverse effect on the ripening when WBPH attacks during maturation period. The flag leaf and panicle are aggressively attacked by nymphs and adults the population of which remain high from early September to mid October.

Rice Leaf Folder Cnaphalocrocis medinalis (Guenee) (Lepidoptera Pyralidae)

The rice leaf folders belonging to Cnaphalocrocis and Marasmia have recently acquired the pest status in rice. However Cnaphalocrocis medinalis has become a major pest of rice causing moderate to severe damage in most of the rice growing regions. In Bihar the infestation of this insect reached to 78.1% leading to 90% yield loss in scented rice. Similarly untreated fields of Basmati rice in Haryana and adjoining areas have been reported to suffer 30 80% loss in yield due to attack of leaf folder which may cause up to 28.5% leaf damage after increasing its population to 20 larvae/hill. Unbalanced use of fertilizers especially excessive application of nitrogenous fertilizers seems to be one of the important factors of increasing menace of leaf folders.

The eggs are laid in batches of 10 to 12 arranged linearly along the middle on either surface of the leaves. One female lays approximately 100 eggs. The damage is caused by caterpillars which fold the leaves longitudinally by fastening margins with silken threads and feeding inside the fold. During feeding the larvae of C.medinalis sit along the length of the leaf blade and scrape out the soft tissues between vascular bundles longitudinally. As a result only bundle unit bundle sheath sclerenchyma the aboxial epidermis and the cuticle are left intact. In severely attacked condition the crop gives scorched whitish appearance of infested plants and consequently of leaves. They create a leaf tube during the later stages of feeding. Several natural enemies viz. Cotesia sp. Trichogramms sp. Bracon sp. etc. have been found parasitizing leaf folder larvae in the field and keeping the population below ET level.

Rice Hispa Dicladispa armigera (Olivier) (Coleoptera Chrysomelidae)

It is widely distributed in Burma China India Nepal Pakistan and Sumatra. Female beetle lay eggs singly near the tip of the leaf blade and partially inserted in the mesophyll tissue of the ventral surface of the leaf. One female lays an average of 55 eggs which hatch in 3 5 days. The grub mines the leaf between

epidermis producing irregular longitudinal white blotches. The adults feed on all portion of leaf producing white parallel streaks along the mid rib of the leaf leaving only the lower epidermis. The damage by this insect is restricted in early stage of the crop.

Integrated Pest Management

Rice ranks second in consumption of chemical pesticides particularly the insecticides. Their indiscriminate use has affected the ecology adversely. In addition to environmental pollution and health hazards this has led to resurgence of pests and pesticide resistance leading to failure of chemical protection and heavy loss to crop. Serious outbreak of hopper burn due to WBPH was observed in Pusa Basmati 1 fields heavily applied with phorate granule in schedule based operation during 2001 at Pantnagar. With the development of several alternate methods of insect control now it is being realized that to tackle the insect pest problems in aromatic rice safely more emphasis should be given on the use of resistant varieties manipulation of agronomic practices conservation and enhancement of natural enemies and need based application of safe insecticide molecules.

Water Management Practices for Rice

In modern rice culture water management is of great importance as it stimulates better crop growth and higher grain production. Water management involves the manipulation of the hydrologic cycle at various stages to make water available when necessary to remove it when there is an excess of it and to improve its quality if required. It thus involves irrigation drainage and the conservation of water. A major factor underlying stagnation in the yield of the rice crop appears to be poor water management.

In the states of Tamil Nadu Jammu and Kashmir Punjab and Haryana where more than 85 per cent of the area is irrigated the yield per hectare are relatively high. The states which have the poorest irrigation have the lowest yields.

Irrigation stabilizes yield. It has been stated that the rainfall during the rainy season in most of the rice growing states in India is generally sufficient for rice cultivation but it is erratic in time space and quantity. This situation either causes drought or floods both of which adversely affect the yield of this crop. With the provision of irrigation facilities the adverse effects of drought can be avoided. Irrigation dams help to control floods and regulate water supply besides stabilizing yields. Statistics show that in Asia during the last 10 years about 10 per cent of the cultivated area in each year has been affected by floods or drought. It has been proved that not only can irrigation ad drainage help to stabilize the yield of the rice crop but well managed water can also increase its yields. Under scientific management the required quantity of water is made available to the crop when needed. Experiments have demonstrated that a 100 per cent increase in yield may be realized with no other changes in agro technical methods than controlled irrigation with proper management.

Table 1. States with poorest irrigation have the lowest yield

Precise data are available on all aspects of water management in our country. These aspects are reviewed in the following sections

The effect of land submergence on the growth and yield of rice

Studies have been undertaken by many workers to determine the effect of land submergence on the growth and yield of rice.

The depth of submergence

The advantages of land submergence led the workers to initiate work to know the optimum depth of submergence for obtaining the maximum yield.

Ganguli working in Assam reported that the water level of 7.62 cm throughout the growth period of rice was the best whereas Pillai inferred that the maintenance of 5.08 cm of standing water with frequent changes

with fresh water resulted in high rice production.

In the black soils of Siruguppa Mysore submergence under 5 cm deep water resulted in the highest grain and straw yield obtained under the following three treatments

1.5 cm submergence

2.saturation to hair cracking and

3.flowing water.

A thin layer of water is sufficient to maximise the yield of rice no additional advantage occurs from very deep submergence which entails only wastage of water.

Bhatia and Dastane found that a depth range up to 0 4 cm seems to be the optimum for high yielding dwarf rice.

The above workers further added that for dwarf rice varieties deeper submergence may be harmful as shown above. Pande and Mitra (1970) found that the grain yield of rice was better under submergence than under mere saturation during summer and spring and also that the crop under shallow submergence (5 ± 3 cm) gave as good a yield as deep submergence (10 ± 3 cm).

Ghildyal and Jana on the basis of pot experiments observed in general that the highest yield was obtained during a cool and dry season with 0 3 cm of water.

The results of the experiments conducted recently under the All India Co ordinated Scheme for Research on Water Management and Salinity have shown that the field submergence under water 5 to 10 cm deep does not produce any significant difference in the yield and hence shallow submergence up to 5 cm is economical.

From an experiment conducted at Bhubaneswar on a sandy loam soil with a pH of 4.9 Sahu and Rout reported that the lowland rice (T 1242) gave the maximum yield when the soil was kept submerged under 15 cm of water. The yield was reduced by 26.4% under field capacity and by 29.2 at 75 per cent available moisture as compared with the yield under deep continuous submergence though the efficiency per unit of water used was higher from the first two treatments.

Nephade and Ghildyal observed in a lateritic sandy clay loam soil with a pH of 5.1 at Kharagpur that the yield of rice was higher under shallow flooding (3 cm) than under deep flooding (15 cm). Chandra Mohan from Tamil Nadu reported that among the various depth of submergence the 5 cm depth of water proved in general to be the optimum depth of submergence for getting the best yield.

According to Ghose et al. a small quantity of water used at shorter intervals was more beneficial to the rice crop than larger quantities at longer intervals.

The results of studies made at Kharagpur on a lateritic soil (pH 5.4 hydraulic conductivity 0.51 cm/hr of low fertility 0.04% N 0.0055% available P and 0.1% available K) under the co ordinated Project for Research on Water Management and Salinity show the monsoon season shallow submergence and deep submergence were as good as saturation for IR. 8 rice because of the effect of rains low evapourative demands. But during summer shallow submergence scored over deep submergence or saturation.

The work done at Chakuli (sandy loam soil) Orissa at Siruguppa (heavy black soil with 50% clay). Mysore and at Roorkee (alluvial soil) Uttar Pradesh under the Co ordinated Scheme showed that submergence up to 5 and 10 cm did not show any significant difference in yield and therefore submergence up to 5 cm only was economical.

The results discussed above show that for tall rice varieties a slightly higher depth of submergence may be tolerated whereas for new dwarf high yielding rice varieties a depth of 5 cm is enough to get a good yield.

Effect of partial submergence

Since the continuous submergence of the field involves a huge quantity of assured water many workers started experiment to find out the critical period of land submergence for economizing on water.

According to Singh et al. Ghosh and Bhattacharya Sen and Dutta Vamadevan and Dastane Chaudhury and Pande tiller initiation primordium initiation and flowering are the most critical stages. A shortage of water during these stages could reduce grain yield appreciably. Therefore submergence at these stages should be practised. Further Ray and Pande emphasized the point that the flowering stage was the most critical period.

The data revealed that the highest grain yield at Chakuli was obtained when the soil moisture was maintained at saturation till tillering followed by submergence under 5 cm of water till harvesting (M1). Continuous submergence (M8) did not show any additional advantage while continuous saturation till flowering brought about a reduction in yield.

At Kharagpur the highest grain yield was obtained during kharif under the treatment in which saturation was maintained till tillering followed by submergence till harvesting (M1) whereas during rabi the treatment submergence till flowering followed by saturation till harvesting (M3) produced the highest grain yield though the treatment saturation till tillering followed by submergence till harvesting (M1) also produced more or less similar yield. Continuous submergence required the greatest quantity of water without any additional benefit in terms of grain yield. The results of another experiment conducted using IR. 8 during kharif 1971 at Kharagpur showed that submergence under 5±2 cm of water maintained only during the active vegetative and reproductive phases and saturation during other phases produced the maximum grain yield.

The result of the studies taken up at Siruguppa (Mysore) also reveal in general that tillering to flowering was the most critical stage when the rice crop should not be subjected to any moisture stress.

Table 2. The effect of moisture stress during different growth stages on the yield of rice

As already stated in most cases the shallow submergence of the fields has been reported to be beneficial. However where the water table is shallow even shallow submergence may be avoided meaning thereby that a reasonably good yield of rice can be obtained by maintaining the rice field just moist (0 3 atm.) to avoid cracking. A number of experiments at the Indian Agricultural Research Institute during kharif have also corroborated this result.

Mane working on rice variety NP. 130 reported that there was a good scope of economising on irrigation water in the rice fields by applying water at 0.2 or 0.5 atm. tension and not going in for continuous submergence.

Rao studied the influence of moisture regimes on the yield and yield components of the rice variety under the conditions of a shallow water table. The results are presented in Table 3.

Table 3 The yield and yield attributes as affected by moisture regimes

Neither the grain yield nor any yield component was influenced significantly by moisture stress up to 0.3 atm. tensions where the water table was shallow. This observation suggests that where the water table is shallow there is no need to submerge the fields.

Recently Jha found a suitable water management practice for rice using the varieties maturing nearly in 115 to 120 days (viz. Sabarmati and Jamuna). He recommended that with a much less quantity of water (by scheduling irrigation at 0.3 atm. tension) in the rice fields as compared with the conventional practice of keeping the water standing in the rice fields a good yield of rice (even better than that from the latter practice) could be obtained by scheduling irrigation in respect of rice at 0 0.3 atm. tension but supplementing the crop with a foliar spray of nitrogen (urea) potassium silicate and ferrous sulphate (under poor Fe status) and controlling weeds with a suitable herbicide. However caution must be exercised to avoid stress during critical stages such as active tillering and flowering. He was of the opinion that the applying of silicate maintained leaf turgidity and the rest of the nutrients compensated for the loss caused by slightly oxidized condition prevailing in the field because of scheduling irrigation at 0.3 atm. tension. The yield and the economics under each water regime are presented in Table 4.

The data presented in Table 4 clearly revealed that though there was an increase in the grain yield by about 4.75 quintals per ha when set off against the extra cost of irrigation water there was a reduction in the net return by about Rs 185. Whereas the applying of a foliar spray of N in preference to the soil application of N120 P60 K40 under the moist regime it was possible to increase the grain yield by about 9 quintals/ha by incurring an additional expenditure of 80 rupees which resulted in an additional net return of Rs 433/ha. Likewise a foliar spray of different nutrients e.g. iron or silicon resulted in a significant increase in the grain yield and in a high net return per hectare over that resulting from the application of fertilizers to the soil.

Water Requirement of the Rice Crop

Earlier studies on the water requirement of the rice crop were directed towards transpiration ratios and were conducted mostly with plants grown in pots. This procedure reduced the significance of these studies. Dastane et al. reviewed the work on the water requirement of crops including rice. According to them the latest definition of water requirement is regardless of source the quantity of water needed to grow a rice crop under field conditions . This definition embraces evapotranspiration application loss (percolation and seepage) and special needs (e.g. the leaching of excess salts and preparing the field). They reported that owing to the difference in the different components of water requirement the water requirements of the same variety or crop may differ widely from place to place.

It seems that water requirement of the rice crop varies widely depending upon the soil climate season varieties and management practices because the above mentioned components are the function of these entities.

Diseases and Pests of Rice and Their Control

The importance of insect pests is generally recognized the damage they do is widespread and very evident but the loss of crop caused by diseases should not be overlooked or considered negligible. The crop is liable to many diseases any one of which may suddenly inflict widespread damage.

In recent years the effect of plant protection has significantly increased. Although average losses in most fields have been appreciably reduced due to adequate plant protection measures losses in individual rice growing areas and fields from specific diseases and pests are at times high and markedly reduce that total grain output in the country.

Practical plant protection includes not only destructive measures but also the use of resistant rice varieties methods that result in unfavourable conditions for the development of injurious organisms and practices that conserve useful enthomofauna. Such protection also allows one to control economically important pests which rely on population thresholds by using in the first place natural limiting factors and then other plant protection methods that are consistent with economical ecological and toxicological requirements.

Rice Diseases

Most of the world s major rice diseases are known to occur in the Soviet Union.

Blast for one is a major disease caused by the fungus Pyricularia oryzae Cav. It occurs in almost all rice producing areas and is the most noxious disease of rice. The fungus mostly attack the leaves and to a lesser extent the nodes and panicles. The disease results in both leaf blast and head blast. The latter condition is where the panicles frequently break over due to infection weakened structural tissues in the panicle and is sometimes known as rotten neck.

Atmospheric moisture and temperature conditions are of primary importance in the infection and spread of the fungus that causes blast. Frequent rains heavy nightly dews high relative humidities and temperature (18 20°C) favour wide scale outbreaks of the disease Rice plants under high levels of nitrogen fertilization are more susceptible to blast. The outbreaks of disease may be caused by use of susceptible varieties or

uncleaned seeds mixed with the seeds of varieties consistently susceptible to blast. Blast is heavier on late sown than on early sown crops. The infection is persistent in seeds on the stubble in straw and reed growths.

The average losses in yield of the fungus affected plants account for 25 percent. The milling yield of head rice is decreased by about 23 25 per cent. Treatment of the rice crop infected with P. oryzae includes spraying with 0.4% zineb solution (80 percent wettable powder) at a rate of 2.4 kg/ha or with rhizid P (50% emulsible concentrate) at a rate of 0.5 1.0 kg/ha in terms of the active ingredient. The rate of application is 200 1/ha. The treatment of the crop should be completed 20 days before harvesting.

Preventive measures include early fall plowing seeding with clean certified seed from the varieties selected best for that area s growing season the application and uniform distribution of nitrogen fertilizer and seed dressing or disinfecting with coloured granosan M dusts at 0.04 kg (active substance) per ton of seed.

Other rice diseases such as brown spot sclerotical rot root rot and bacterial disturbances are rare and of less economic significance.

Recommended control and prevention practices against fungi and bacteria attacks include the removal of rice straw burning of plant residue deep fall plowing with inversion of the soil layer and rotational planting (with cultivated fallows and leguminous grasses). Seed dressing with coloured granosan M dusts (0.04 kg/ton active substance) is mandatory.

General symptoms of rice diseases are abnormal plant growth and changing leaf colour. A disturbance in plant development manifestes itself in retarded growth and excessive or reduced tillering. The stems and leaves may develop galls or cecidia streak mozaic and necrotic areas. The leaf may change its coloration from green to yellow green or yellow orange. Diseases are transmitted basically by suctorial insects. To prevent the spread of such diseases rice fields are treated with phosphororganic substances in the early stages of plant development to kill cicads (Cicadidae) insect vectors of virus and micoplasma inhabiting clumps of grasses particularly barnyard grass.

White tip disease of rice caused by an ectoparasitic foliar nematode Aphelenchoides besseyi Christie is another widespread noxious disease of rice.

The most distinguishing symptom of white tip is the presence of leaves with white tips of 2.5 5 cm long. The tips of the developing leaves may be twisted and wrinkled and the flag leaf may be twisted and wrinkled and the flag leaf may be twisted near the panicle. The infected plants are generally stunted.

The nematodes are seed borne and are spread from one crop to the next in seed rice and stubble. They become active after rice is sown and migrate towards the growing point of the young rice plants where the nematode feed and reproduce. Anywhere from 8 to 13 generations can be reproduced during a growing season. Feeding injures the developing leaves and panicles before emergence. Later on the injuries are white necrotic leaf tips and small sterile panicles. Grain yields from diseased plants are markedly reduces.

Several methods can be used to control white tip. Resistant seed varieties nematode free seed should be used in planting re cleaned seed lots free from shrunk and light weight seeds can be used for seeding. Infected rice straw should be removed from the fields and burnt. Fall plowing and rotations also help control or prevent the spread of white tip in rice.

Pests of Rice

Several pests frequently damage rice severely. Among them is the larva of Dioptera and Orthoptera which may cause serve injury by feeding on young rice plants particularly in rice grown in saline soils. Economically important population thresholds constitute 40 larvae per 1 sq. m.

The tadpole shrimp Triops (Apus) cancriformis Schaft. although not an insect is also a pest of rice. The adult spherical shield shaped shrimp is about 3.0 3.5 cm long. The eggs are ball shaped reddish black and 0.4 mm in diameter and are laid by the female shrimp in water or soil. This gives the eggs shelter for

many years after water is withdrawn. In the spring 3 to 4 days after flooding the field the eggs hatch and the young larvae or maggots as they are commonly called emerge to become fully grown adults in 14 15 days. The young larvae first feed on the organic matter and within 8 9 days reach 7 10 mm in length. They then migrate to the rice and cause severe injury by pruning the young roots and shoots. Germinating seeds lying on the soil surface become easy targets for the maggots. The tadpole shrimp survives for one generation and late in June it disappears.

Since the immature stages are spent underwater among the rice roots most of the shrimps larvae can be destroyed by draining the fields and allowing them to dry for a day or two. Appropriately leveled checks timely opened drainage furrows and peripheral ditches are essential for rapid drainage.

Esteria (lumnadia) Leptestheria spp. a shellfish is another aquatic pest of rice its body is enclosed in a bivalve translucent shell and is 9 10 mm long and 4 5 mm broad in fully developed specimens. It moves with the use of its antennae and lays its eggs in a shell. Its white ball shaped eggs are 0.13 mm in diameter and dropped into water as they accumulate within the shell. The eggs settle on the soil surface and may stay there for years. Three days after the field is flooded the eggs laid in the previous season hatch and larvae emerge.

Esteria matures within 8 to 10 days the first 5 to 7 of which are spent feeding on organic matter. Upon reaching maturity the full grown Esteria quickly migrates to the soil surface and begins to feed on the young rice plants. What ensues is the destruction of a significant number of these plants. The life cycle of Esteria is one generation and it can be found in rice fields until late June.

Draining and withholding water for 1 2 days controls larvae development by disturbing its life cycle thus eliminating the risk of injury to rice seedlings.

The caddis fly (Trichoptera) Limnophylus stigma is an insect pest of rice. Several species of this numerous insect order are present in the Far East and Central Asia injuring rice severely in certain years. The 10 16 mm long larva is what inflicts damage on the rice plants. The larva lives in the water enclosed in a cigar shaped tube that it builds around its body from minute plant debris and trash. The tube size varies from 12 to 20 mm. The larva holds the tube fast on its body with its last body segment and moves about with its head and three pairs of thorax legs. The larvae migrate to rice fields and feed on rice seedlings thus reducing the density of plant stands.

Draining the field for 1 2 days or treating it with chlorinated lime at a rate of 10 12 kg/ha helps control the caddis fly.

The barley leaf miner Hydrellia griseola Fall. is a dangerous pest of young rice in the Far East Northern Caucasus and the Ukraine. A grey fly 2.5 mm long the miner usually infests rice fields in April and in the Far East in May. Its white eggs elliptical in shape and 0.6 mm long are laid on the upper leaf surfaces and along the veins of rice leaves that are afloat. Damage is done 2 3 days after the eggs hatch and the maggots appear. The miner maggots attack the leaves and feed on their parenchyma. This reduces the photosynthetic capacity of the leaves and consequently impairs the rice yield. The pale yellow maggots are elliptical and 3.0 3.5 mm long. They pupate in the mines they have made in the leaves and develop pale brownish pupa. Within 6 9 days they emerge as flies. The barley leaf miner produces 3 4 generations and attacks all rice seedlings regardless of the date of seeding.

Lowering the water or draining the fields for 2 3 days or treating fields with a 20% emulsifiable methaphos at 0.2 0.4 kg/ha (active ingredient) provides reliable control of egg and larva population.

The rice leaf miner Hydrellia griseola var. scapulasis Loew is a destructive pest of rice in the Far East. The black flies are 3.3 3.8 mm long and lay eggs on the leaf tip tissue. They attack rice in June. The maggots are yellow green 4 6 mm long when hatched and feed within the leaf working their way towards its base. The larvae pupate on the top of the damaged leaf which turns brown and lies prostrate on the water. Infestation leads to a reduction in yield. The rice leaf miner produces three generations of which the first

two are most damaging to rice. Preventive measures include adequate weed control and proper water management.

The rice midge Chirono mus spp. is a destructive pest of rice in the Far East Northern Caucasus and the Ukraine. Only occasionally does the insect infest rice in Central Asia. Light attracts the midge and can be used to determine when the midge is attacking the rice fields. Such attacks usually occur in April. The eggs laid in water hatch yellowish translucent larvae within 2 3 days. The larvae first feed on organic matter and rice roots. During this time the injury to the rice is insignificant. The adult larvae 8 mm long infest the lower surface of leaves that are afloat and feed on the parenchyma. This causes the leaves to wither and reduces yield. The rice midge produces three generations and damages all rice seedlings regardless of the date of seeding. It is most damaging when the rice plants are excessively flooded and the leaves stay afloat for a long time on the water surface. Lowering the water level or draining the rice fields for 2 3 days provides effective control of the midge larvae. Treatment of the fields with a 20% emulsifiable methafos at a rate of 0.2 0.3 kg/ha by aircraft sprayers is also effective on large larvae population.

The shore fly Ephydra macellaria Egg. infests rice in almost all rice growing areas. The fly is 4 mm long. Its thorax and abdomen are metallic green its legs reddish green. Its wings are large and translucent. It lays about 80 to 90 eggs in the water covering rice checks. The larvae are what is destructive to rice as they are adapted to live in water. Where they feed on young rice roots. Such feeding results in the withering and reduced rice plant stands. The larvae pupate where they feed i.e. on roots stems and leaves and emerge as flies within 8 to 12 days. The fly produces 3 4 generations. When larvae population counts are high withholding water for a day or two may provide adequate control. Treatment of field with 80% emulsifiable chlorophos powder at a rate of 0.8 1.6 kg/ha is also effective in controlling large larvae populations.

The rice water weevil Hydronomus sinuaticollis Fst. is found in all rice growing areas of the Far East and Central Asia. The adult weevil is black 4 5 mm long and has two light spots on the elytra. The male water weevil is smaller than the female. In the post feeding stage the larvae overwinter in the plowed up soil at a depth of 5 8 cm. The larvae are milky white legless and about 7 8 mm long when fully grown. They pupate in the spring and emerge as weevils in May or June. The weevil feeds on germinating seeds and roots of young rice. Rice that is sown late is usually more susceptible to the weevil. Eggs are laid in the root zone. The hatched maggots live first in the plant and later migrate to prune the roots. Infested plants either die or grow more slowly forming small panicles with poorly set kernels. Rotations disking the stubble in the spring fall plowing and seeding at optimum dates help prevent and control the rice water weevil.

The rice leaf beetle Lema suvorovi Jacobs var. oryzae is a widespread and destructive pest in the Far East. The bugs 4 5 mm long have blue elytra and yellow head and prodorsum. They feed on rice leaves. The female bug lays chains of 6 to 12 eggs on the upper surface of the leaf in late May and early June. The eggs hatch and larvae emerge which feed on leaves and in mid June when they complete feeding they pupate and emerge as bugs 10 12 days later. The rice leaf beetle produces two generations the first of which is the most damaging to rice. Bugs of the second generation spend the winter in the soil or in dry grass straw and other material that affords them shelter. In the spring then they infest primarily the weed plants. Proper weed control and treatment with 80% emulsifiable chlorofos at 0.8 1.6 kg/ha (in terms of active ingredient) reduces the number of bugs in subsequent season.

The cereal aphid Aphididae attacks rice in the Northern Caucasus the Ukraine and Central Asia. Aphids are most destructive to rice sown late in the spring on soils deficient in nitrogen. Some species are winged others wingless. The economically significant level of infestation (population threshold) is 1 2 aphids per square meter at leaf tube formation. The appearance of aphids in rice can be controlled by proper and timely weedings and treatment of fields with 20% emulsifiable methaphos at 0.2 0.3 kg/ha (active substance).

Many other species of insects and various other pests infest rice fields by migrating to rice from the leaves and weed growths. Feeding on rice is supplementary for most of them so if rice cultivation practices are adequate the infestations seldom cause enough damage to reach economically significant levels.

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