# QUANTIFICATION AND PRIORITIZATION OF CONSTRAINTS CAUSING YIELD LOSS IN RICE (*Oryza sativa*) IN INDIA

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***Abstract***

*The present study was carried out in Tamil Nadu State of India to quantify and prioritize the constraints causing yield loss in rice. Data were collected from 120 scientists across various disciplines working on rice. Priorities were arrived then by comparing the relative yield losses caused by constraints and ranking them. The total loss in Tamil Nadu was 2.73 million tonnes accounting for about 39 per cent of production. Leaf folder emerged as the major constraint in the study area. The present study attempted to prioritize those constraints by bringing them under the purview of research aimed to eliminate their ill effects on rice yield.*

**Key words:** *Quantification; Prioritization; Rice and Constraints.*

## INTRODUCTION

Rice is the staple food of more than 60 per cent of the world's population especially for the people in South-East Asia. Among the rice growing countries, India has the largest area under rice crop and ranks second in production next to China. It occupies about 23.3 per cent of gross cropped area of the country and plays a vital role in the national food grain supply. Rice alone contributes 43 per cent of total food grain production and 46 per cent of total cereal production of the country. The average rice productivity in India was 3049.60 kg/ha (2004), which is 23.83 per cent below the world's average productivity of 4003.80 kg/ha during the same year. Rice productivity in the country fluctuates significantly from region to region due to various factors such as pest and diseases, soil type, soil fertility, rainfall pattern, flood, drought, water logging and climatic conditions.

India, with its current population would be the most populous country in the world by 2030. Apparently, rice production does not keep pace with the burgeoning population at a growth rate of 1.93 per cent per annum and has come to stagnation in recent years. With almost no hope for increasing the area under rice production, only way out for production increment is to increase the productivity of rice lands in future.

The approach should be to identify the constraints that operate to keep rice yields significantly below their potential maximum and find the yield gap. Yield gap is not identical for all environments. It is explained by a number of constraints - pests, diseases and management and decomposed into two parts *viz.,* Yield gap I and Yield gap II. Yield gap I is the difference between an experimental station's maximum yield and an on-farm experiment's maximum yield. This yield gap arises from differences in environment, which cannot be managed in the farmer's field. Yield gap II was the primary concern of present study, because, it is the difference between actual farm yield and yield attained in on-farm experiments. This gap reflects the presence of significant constraints. In a study conducted by Tamil Nadu Agricultural University in Tamil Nadu state, the average yield (5.16 tonnes/ha) realized by farmers during *Kharif* season was below the average potential yield (5.68 tonnes/ha) resulting in an yield gap of 10.13 per cent. Likewise, the gap was estimated to be 12.83 per cent during *Rabi* season (C.Ramasamy *et al.*, 1997).

Occupying the extreme south of the Indian peninsula, Tamil Nadu is an agrarian state having 18.73 lakh hectares under paddy. The state contributes about 5 per cent of total rice production in the country with an average productivity of only 2702 kg/ha (2004-05). The present study would identify and quantify the rice productivity constraints responsible for yield gap of rice in the state of Tamil Nadu in India. Constraint analysis as conceived in the present study identifies pests, diseases and mismanagement factors impeding higher farm yield.

## MATERIALS AND METHODS

In order to develop location specific constraint solving rice production technologies that are ecologically, economically and culturally sustainable, it becomes mandatory to identify specific farming situations with reference to different agro-climatic zones existing in Tamil Nadu. The variations may be observed in terms of soil structure, texture, soil depth, soil reaction, drainage, land shape and variations in moisture regime linked with rainfall and irrigation. For the present study, the agro-climatic zones that have been delineated under National Agricultural Research Program were adopted as study zones within the state (Appendix I). Further, we had to resort to this classification; because regional rice research is organized on the basis of agro-climatic zones and research resource allocation are zone-based.

All the zones except high altitude zone possess a favourable environment for rice production. Though

production environments vary, rice is the dominant crop. In the present study, for each agro-climatic region specific rice production environment, absolute quantity of yield loss attributed to each constraint was estimated. The constraints identified in the region are specific to sub-production environments within the region. To be precise and authentic in estimation of yield loss, scientists from whom primary data was collected were asked to estimate yield loss due to the constraints, which are relevant to their area of specialization. For instance, an entomologist would estimate yield loss due to insects and pests that are above economic threshold level. The average yield loss due to a particular constraint over the last five years (2001-2005) was considered as loss due to that constraint. Finally sum of losses across the regions gives the total production foregone to each constraint in each zone. To cross check the yield loss estimates due to production constraints obtained from scientists, views of the extension personnel having field experience in rice production in that region was considered.

## RESULTS AND DISCUSSION

### Major Constraints and their Occurrence in Tamil Nadu

Rice is highly adaptable plant grown under different ecological conditions in sub-tropical and tropical regions. Accordingly, rice production constraints too are more in number. At the first stage, the major constraints in rice production and their magnitude of severity have been identified. With the completion of the initial survey, prevalence of different constraints in Tamil Nadu became clear and 37 constraints, which have economic significance, were identified and furnished in Table 1. Another interesting finding was the coincidence of constraint ratings in a given rice environment in each of the zones of Tamil Nadu among scientists and extension personnel. Obviously, there are idiosyncrasies or special cases across the zones, but the major constraints were quite uniform.

In addition, we observed that across rice environments, while the major constraints (i.e. pests, diseases and management) were similar, the minor constraints often differed quite dramatically. Thus, there is a common set of major constraints and variety of minor constraints across the zones. Because there is a considerable overlap, we present the findings of the first phase by describing generally the major and minor constraints identified across all rice production environments.

### Production Loss

The respondents, 120 scientists engaged in rice research and equal number of extension personnel, provided estimates of yield loss due to each constraint for their respective agro-climatic zones. However, this does not mean that all these constraints were major and occur simultaneously. These may occur in most severe form in any one of the regions in one of the seasons. Hence, it would not be realistic to give equal importance to all constraints. The estimates of yield loss were furnished in Table 2. Ranking of the top twenty constraints on the basis of yield loss estimates for Tamil Nadu is presented in Table 3. Since the rankings were ordinal, it was not possible to compare the severity of constraints when the relative ranking across the zones changed. Thus, the identification procedure indicated whether a constraint was a major one in a particular zone or production environment. Only the constraints causing major production losses were discussed in the following pages for the zones surveyed.

Rice cultivation is not done in high altitude zone. Hence, out of seven, six zones were considered for the present study. The total loss in Tamil Nadu was 2.73 million tonnes, that is, about 39.45 per cent of production. There existed a yield gap of 39.45 per cent, which if brought down would be the actual productive potential of the crop. Pests, diseases, and mismanagement contributed to the production loss by 42.23, 21.17 and 36.59 per cent respectively. Among pests, leaf folder emergence was the most serious one followed by stem borer and ear head bug accounting for about 11.18, 9.17 and 5.59 per cent of losses. Amongst diseases, blast an endemic disease in Tamil Nadu where relative humidity is high caused about 7.20 per cent of losses. Drought / water scarcity is a common phenomenon in Tamil Nadu and hence should be a major constraint in management aspect contributing losses to the tune of 7.69 per cent. Aged seedlings, weeds and long duration were other constraints sharing about 4.55, 4.10 and 4.04 percent of losses.

Across the zones, leaf folder caused maximum yield loss in the CDZ, SZ, NEZ and HRZ; whereas it was next only to yellow stem borer in WZ and NWZ. Other insects causing major losses were ear head bug, BPH and green leafhopper. Leaf folder (*Cnaphalocrocis medinalis*) assumed the status of major pest after the introduction of high yielding nitrogen responsive varieties. The pest at its larval stage feeds the young leaves by scraping them, finally folds the leaves together by connecting two margins of a blade through series of threads that the caterpillar secretes. The discoloration and folding of leaves affects the general vigour of plants and reduce their photosynthetic ability. Damaged leaves also predispose the plants to fungal and bacterial infection.

Rice blast incidence is endemic in areas where humidity is high and it ranked second in HRZ and third in SZ and WZ. The other disease causing yield loss to a significant level is RTV. It is suggested that biotechnological intervention would be the effective way to solve yield loss due to pests and diseases (Table 4).

Drought / water scarcity was a common constraint in SZ, NEZ and NWZ of Tamil Nadu. On the contrary lodging/flooding was a common constraint in HRZ and CDZ. Natural calamities like frequent cyclone and floods were responsible for this constraint and evolving of varieties resistant to lodging through hybridization

could be the solution. There is another rather disturbing aspect of rice production, is that of weed and it ranked sixth in WZ, and twelfth in SZ and NEZ of Tamil Nadu. The problem is very acute in tail end farms where water stress is quite a common phenomenon and weeds aggravate to the problem by competing with rice for water and nutrients. Adoption of efficient water management and cultural practices is considered crucial for the successful control of weeds.

Salinity problem is widely prevalent in water logged and coastal zones of Tamil Nadu, which is due to poor drainage system. Though drainage facilities were well conceived and implemented several decades ago, they are not properly maintained. Large-scale encroachments made drainage channels inoperative and ignored. According to scientists, breakthrough in controlling these problems can be achieved by evolving varieties tolerant to salinity through hybridization and creation of awareness among the farming community. Apart from these problems, imbalanced fertilization is found to be a common problem prevalent in all the zones but at different levels. This can be overcome by fertilizing the soil at optimum after soil testing and creation of awareness among the farmers regarding the judicious use of fertilizers.

## SUMMARY

The constraints identified across zones need immediate attention of policy makers and agricultural research scientists. It is interesting to note that biotechnology as suggested by scientists emerges to be a preferred method in solving majority of the constraints. The result is quite expected as biotechnology ensures both economic (cost effective) and environmental benefits. Evidently, the future allocation of research resources must be biased more towards biotechnology.

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**Tab. 1:** Productivity constraints of rice identified in Tamil Nadu

| **RICE PESTS** | **RICE DISEASES** |
|---|---|
| Yellow stem borer | Rice blast |
| Leaf folder | Brown spot |
| Ear head bug | Sheath blight |
| Brown Plant Hopper (BPH) | Sheath rot |
| Green Leaf Hopper (GLH) | Rice Tungro Virus (RTV) |
| Thrips | Rice yellow dwarf |
| Gall midge | Grain discoloration |
| Whorl maggot | Bacterial Leaf Blight (BLB) |
| Rodents | **RICE MANAGEMENT** |
| Cut worm | Drought / Water Scarcity |
| Case worm | Duration |
| Rice hispa | Zinc deficiency |
| Mealy bug | Iron deficiency |
| Leaf Mite | Imbalanced fertilization |
| White tip nematode | Aged seedlings |
| Black bug | Weeds |
| White Backed Plant Hopper (WBPH) | Salinity |
| Termite | Lodging / Flooding |
| Root nematode | Alkalinity |

**Tab. 2:** Loss due to production constraints in Tamil Nadu

(in '000 Tonnes)

| **Constraints** | **CDZ** | **SZ** | **NEZ** | **WZ** | **NWZ** | **HRZ** | **TN** |
|---|---|---|---|---|---|---|---|
| **PESTS** | | | | | | | |
| Yellow Stem Borer | 91.97 | 44.47 | 87.54 | 11.84 | 13.26 | 1.08 | 250.17 |
| Leaf Folder | 112.90 | 62.36 | 104.69 | 10.17 | 13.12 | 1.92 | 305.16 |
| Ear Head Bug | 84.15 | 35.68 | 16.43 | 7.47 | 7.94 | 1.00 | 152.67 |
| Brown Plant Hopper | 99.33 | 2.42 | 8.69 | 1.91 | 2.55 | 0.59 | 115.48 |
| Green Leaf Hopper | 9.66 | 1.04 | 59.61 | 1.46 | 0.50 | 0.33 | 72.59 |
| Thrips | 11.95 | 0.78 | 3.74 | 1.23 | 0.35 | 0.20 | 18.25 |
| Gall Midge | 14.55 | 7.12 | 16.36 | 1.90 | 1.23 | 0.46 | 41.63 |
| Whorl Maggot | 3.46 | 0.74 | 37.41 | 0.61 | 0.39 | 0.16 | 42.76 |
| Rodents | 20.59 | 24.56 | 12.86 | 2.35 | 2.58 | 0.58 | 63.51 |
| Cut Worm | 1.70 | 0.41 | 0.16 | 0.11 | 0.10 | 0.07 | 2.56 |
| Case Worm | 0.99 | 0.32 | 0.53 | 0.06 | 0.20 | 0.03 | 2.12 |
| Rice Hispa | 2.04 | 0.28 | 0.68 | 0.12 | 0.09 | 0.02 | 3.22 |
| Mealy Bug | 0.80 | 0.34 | 0.76 | 0.16 | 0.21 | 0.07 | 2.34 |
| Leaf Mite | 1.81 | 0.90 | 0.85 | 0.14 | 0.11 | 0.03 | 3.85 |
| White Tip Nematode | 1.21 | 0.82 | 0.15 | 0.16 | 0.10 | 0.03 | 2.47 |
| Black Bug | 3.77 | 0.47 | 48.95 | 0.14 | 0.29 | 0.03 | 53.64 |
| White Backed Plant Hopper | 1.71 | 0.75 | 0.14 | 0.07 | 0.20 | 0.03 | 2.90 |
| Termite | 1.12 | 1.88 | 1.29 | 0.25 | 0.10 | 0.02 | 4.66 |
| Root Nematode | 8.59 | 2.05 | 0.80 | 0.85 | 0.13 | 0.07 | 12.49 |
| ***Sub Total (a)*** | ***472.30*** | ***187.37*** | ***401.65*** | ***41.02*** | ***43.42*** | ***6.71*** | ***1152.47*** |
| **DISEASES** | | | | | | | |
| Rice Blast | 75.86 | 46.09 | 54.26 | 8.41 | 10.61 | 1.13 | 196.36 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Brown Spot | 19.65 | 10.31 | 14.40 | 1.19 | 2.66 | 0.41 | 48.61 |
| Sheath Blight | 11.43 | 6.27 | 4.00 | 0.82 | 2.45 | 0.75 | 25.72 |
| Sheath Rot | 18.47 | 21.63 | 6.11 | 1.55 | 3.57 | 0.68 | 52.00 |
| Rice Tungro Virus (RTV) | 38.01 | 8.80 | 85.61 | 1.91 | 4.13 | 0.58 | 139.04 |
| Rice Yellow Dwarf | 13.45 | 0.89 | 0.47 | 0.26 | 0.72 | 0.03 | 15.82 |
| Grain Discoloration | 9.24 | 2.44 | 1.69 | 0.44 | 1.22 | 0.12 | 15.15 |
| Bacterial Leaf Blight | 67.15 | 5.42 | 8.97 | 1.54 | 1.93 | 0.09 | 85.09 |
| ***Sub Total (b)*** | ***253.26*** | ***101.84*** | ***175.51*** | ***16.11*** | ***27.28*** | ***3.80*** | ***577.80*** |
| **MANAGEMENT** | | | | | | | |
| Drought / Water Scarcity | 37.25 | 59.21 | 98.49 | 2.11 | 12.36 | 0.33 | 209.75 |
| Duration | 16.37 | 39.25 | 39.34 | 3.95 | 10.78 | 0.52 | 110.21 |
| Zinc Deficiency | 44.21 | 9.16 | 29.98 | 1.81 | 3.42 | 0.03 | 88.62 |
| Iron Deficiency | 27.33 | 2.41 | 3.57 | 1.00 | 1.35 | 0.01 | 35.67 |
| Imbalanced Fertilization | 49.28 | 28.08 | 11.78 | 1.90 | 3.20 | 0.59 | 94.84 |
| Aged Seedlings | 46.50 | 32.47 | 37.85 | 2.35 | 3.99 | 0.87 | 124.04 |
| Weeds | 64.73 | 13.89 | 29.52 | 2.38 | 0.73 | 0.56 | 111.81 |
| Salinity | 59.05 | 18.59 | 4.97 | 1.69 | 2.93 | 0.04 | 87.27 |
| Lodging / Flooding | 61.78 | 0.17 | 7.72 | 1.10 | 0.64 | 0.89 | 72.29 |
| Alkalinity | 44.21 | 10.38 | 6.60 | 1.52 | 1.36 | 0.07 | 64.14 |
| ***Sub Total (c)*** | ***450.72*** | ***213.59*** | ***269.83*** | ***19.81*** | ***40.76*** | ***3.91*** | ***998.63*** |
| **TOTAL (a+b+c)** | **1176.28** | **502.81** | **846.99** | **76.94** | **111.47** | **14.42** | **2728.91** |

**Tab. 3:** Ranking of rice yield constraints by rice production zones

| Rank | CDZ | SZ | NEZ | WZ | NWZ | HRZ | Tamil Nadu |
|---|---|---|---|---|---|---|---|
| I | Leaf folder | Leaf folder | Leaf folder | Yellow stem borer | Yellow stem borer | Leaf folder | Leaf folder |
| II | BPH | Drought / Water Scarcity | Drought / Water Scarcity | Leaf folder | Leaf folder | Rice blast | Yellow stem borer |
| III | Yellow stem borer | Rice blast | Yellow stem borer | Rice blast | Drought / Water Scarcity | Yellow stem borer | Drought / Water Scarcity |
| IV | Ear head bug | Yellow stem borer | RTV | Ear head bug | Duration | Ear head bug | Rice blast |
| V | Rice blast | Duration | GLH | Duration | Rice blast | Lodging / Flooding | Ear head bug |
| VI | BLB | Ear head bug | Rice blast | Weeds | Ear head bug | Aged seedlings | RTV |
| VII | Weeds | Aged seedlings | Black bug | Rodents | RTV | Sheath blight | Aged seedlings |
| VIII | Lodging / Flooding | Imbalanced fertilization | Duration | Aged seedlings | Aged seedlings | Sheath rot | BPH |
| IX | Salinity | Rodents | Aged seedlings | Drought / Water Scarcity | Sheath rot | Imbalanced fertilization | Weeds |
| X | Imbalanced fertilization | Sheath rot | Whorl maggot | BPH | Zinc deficiency | BPH | Duration |
| XI | Aged seedlings | Salinity | Zinc deficiency | RTV | Imbalanced fertilization | RTV | Imbalanced fertilization |
| XII | Zinc deficiency | Weeds | Weeds | Gall midge | Salinity | Rodents | Zinc deficiency |
| XIII | Alkalinity | Alkalinity | Ear head bug | Imbalanced fertilization | Brown spot | Weeds | Salinity |
| XIV | RTV | Brown spot | Gall midge | Zinc deficiency | Rodents | Duration | BLB |
| XV | Drought / Water Scarcity | Zinc deficiency | Brown spot | Salinity | BPH | Gall midge | GLH |
| XVI | Iron deficiency | RTV | Rodents | Sheath rot | Sheath blight | Brown spot | Lodging / Flooding |
| XVII | Rodents | Gall midge | Imbalanced fertilization | BLB | BLB | GLH | Alkalinity |
| XVIII | Brown spot | Sheath blight | BLB | Alkalinity | Alkalinity | Drought / Water Scarcity | Rodents |
| XIX | Sheath rot | BLB | BPH | GLH | Iron deficiency | Thrips | Black bug |
| XX | Duration | Grain discoloration | Lodging / Flooding | Thrips | Gall midge | Whorl maggot | Sheath rot |

**Tab. 4:** Research methodologies identified by scientists for major constraints in Tamil Nadu

| **Constraints** | **Methods of Research** |
|---|---|
| Leaf Folder | Biotechnology |
| Yellow Stem Borer | Biotechnology, Conventional Breeding |
| Drought / Water Scarcity | Biotechnology |
| Rice Blast | Biotechnology, Conventional Breeding |
| Ear Head Bug | Biotechnology, Conventional Breeding |
| RTV | Biotechnology, Conventional Breeding |
| Aged Seedlings | Cultural |
| BPH | Biotechnology, Conventional Breeding |
| Weeds | Chemical and Cultural |
| Duration | Biotechnology, Conventional Breeding |
| Imbalanced Fertilization | Chemical and Cultural |
| Zinc Deficiency | Chemical and Cultural |
| Salinity | Biotechnology, Conventional breeding |
| BLB | Biotechnology, Conventional Breeding |
| GLH | Biotechnology, Conventional Breeding |
| Lodging / Flooding | Biotechnology, Conventional Breeding |
| Alkalinity | Biotechnology, Conventional breeding |
| Rodents | Chemical and Cultural |
| Black Bug | Biotechnology, Conventional Breeding |
| Sheath Rot | Biotechnology, Conventional Breeding |

**Appendix I**

Classification of agro-climatic zones in Tamil Nadu

| Zones | Characteristics | Districts |
|---|---|---|
| Cauvery Delta Zone (CDZ) | Canal and well-irrigated environments – lies in the eastern part of the state – rice is the most important crop covering 95 per cent of the area. Major area is occupied by the alluvial deposits and generally fertile – the zone is humid tropic with high humidity | Thanjavur<br>Nagapattinam<br>Thiruvarur<br>Trichy<br>Karur<br>Perambalure |
| Southern Zone (SZ) | Tank, canal and well irrigated environments – comprises of the southern plains and foot hills of Western ghats – topography is undulating and tapered towards east coast – major portion of this zone lies on the rain shadow of Western ghats – prone to frequent droughts – climate is semi-arid tropic. | Pudukottai<br>Madurai<br>Dindigul<br>Theni<br>Ramnathapuram<br>Sivagangai<br>Virudhunagar<br>Thirunelveli<br>Thoothukudi |
| North Eastern Zone (NEZ) | Canal and tank irrigated environments – has long coastal line on the eastern side – benefited by both monsoons – cyclone is often experienced – there are four soil types: red, black, river alluvial and coastal alluvial – rice is the major crop followed by groundnut | Kancheepuram<br>Thiruvallur<br>Vellore<br>Thiruvannamalai<br>Cuddalore<br>Villupuram |
| Western Zone (WZ) | Well and canal irrigated environments – completely land locked zone – soil is predominantly red with a block of black soil – climate is from semi-arid to sub humid – the seasons are southwest monsoon, northeast monsoon, winter, and summer – sorghum, groundnut, followed by rice are the major crops | Erode<br>Coimbatore |
| North Western Zone (NWZ) | Well and canal irrigated environments – zone is completely landlocked covering 12.4 per cent of the state area – soil types are red, black, river alluvial patches of saline and alkaline soils are found – there are 4 seasons; south west monsoon, north east monsoon, winter and summer – irrigation through wells, canals and tanks supplemented by rivers. | Salem<br>Namakkal<br>Krishnagiri<br>Dharmapuri |
| High Rainfall Zone (HRZ) | Canal irrigated environment – situated in the southern most part of the state – well distributed rainfall in South West monsoon, North East monsoon and Summer season – soil is deep red loam – rice is the only annual crop grown extensively | Kanyakumari |
| High Altitude Zone (HAZ) | No rice production is followed – the Palani hills of Western ghats comprise this zone – climate is cool and uniform through out the year – soils are red and laterite – irrigation sources are mainly of perennial streams – plantation and horticultural cropping system is predominant | Nilgiris |