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IMPACT OF DROUGHT AND FLOOD ON PRODUCTIVITY AND OCCURRENCE OF PESTS AND DISEASES

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Both flood and drought have been found to adversely affect yield as well as productivity. Extreme conditions of drought and flood may result in total loss of yield. Under conditions of drought which cause water stress and flood resulting in waterlogging, the productivity is impaired, the effect being more pronounced under conditions of drought.

Both drought and flood have an impact on the occurrence of pests and diseases, but the extent of losses incurred to pests and diseases under conditions of drought and flood is not precisely known. In 1981, the Rice Tungro Virus (RTV) affected paddy in kharif in South Bengal under conditions of drought and caused appreciable yield losses. Damages caused by pests and diseases under conditions of drought and flood may be both direct and indirect in favouring the build up of pest and disease populations and in rendering the host plants more susceptible to attacks. Indirect effects have been noticed in the case of rice blast *Pyricularia oryzae* where lack of moisture interferes with the silicification of the host tissues rendering them prone to blast attack. Under conditions of drought which often affects the growth of plants including leaves, infection caused by *Helminthosporium* spp. is normally more abundant as these pathogens are normally more active when the hosts are under physiological stress. Drought condition as well as waterlogging have a predisposing effect on root rot as has been noticed in the case of guava *(Psidium gaujava)*. Waterlogging due to flood conditions favours sugarcane wilt caused by *Cephalosporium sacchari*. Bacterial diseases are not normally favoured under drought conditions which are accompanied by low humidity. Flooding of soil tends to eliminate soil pathogens which are strictly aerobes.

Some pests such as certain borers, subterranean species e.g. termites, molecrickets, grubs, beetles are more prevalent when drought prevails. Rice nematodes, *Hirschmaniella oryzae*, *Meloidogyne* spp. have been found to cause more damage when rainfall is infrequent and insufficient. Rice leaf folders have been found to be more active during dry spells whereas rice pests such as gall midges *Nymphula*, brown plant hoppers, green leaf hoppers, yellow stem borers are favoured under wet conditions. Mites are more damaging when dry weather prevails.

Flood often favours the transportation of seeds of the root parasites *Orobanche* spp. to areas where they have not previously recorded. They often bring about mass movement of army worms or swarming caterpillar into areas not affected by flood.

Key words : Drought, Flood, Productivity, Pests

INTRODUCTION

Periodic occurrence of drought due to rain deficit or flood due to excess of rainfall particularly at critical periods constitute major deterrant factors in crop production. Growth and yield of different crop plants depend on a number of factors which include favourable environmental conditions of which the dominant role has to be attributed to the availability of adequate moisture conditions Hence total yield as well as productivity of a crop are adversely affected by both drought and flood. Extreme weather conditions are likely to have an effect on diseases and pests as development of diseases or the degree of infestation by pests depend mainly on three factors, namely the vulnerability of the host, the virulence of the pathogen and the quality of environmental conditions. An attempt has been made to review the effect of drought and flood on the productivity as well as on the incidence of diseases and pests.

PRODUCTIVITY, PESTS AND DISEASES UNDER FLOOD AND DROUGHT CONDITIONS

Effect of drought and flood on productivity

A large number of data is available on the effect of drought and flood on total yield of major crops in different countries of the world. Table 1-4 illustrate the effect of drought and flood on yield and productivity. It is evident that both these factors have an adverse impact on productivity, consequently on the total production.

Table 1. *Effect of drought on productivity of rice in India*

Year	Area (10^3 ha)	Production (10^3 million t)	Av. yield (t/ha)	Remarks
1970-71	37,432	42,448	1.13	
1971-72	37,758	43,068	1.14	
1972-73	36,668	39,245	1.07	Partial drought
1973-74	38,285	44,051	1.15	
1974-75	37,558	39,579	1.04	Acute drought
1975-76	39,475	48,740	1.24	
1976-77	38,606	42,787	1.10	Partial drought
1977-78	40,282	52,670	1.31	
1978-79	40,146	53,829	1.34	
1979-80	39,414	42,330	1.07	Acute drought
1980-81	39,773	53,231	1.34	

Gross effect of drought or flood on the incidence of diseases and pests

Amongst various physical factors of the environment, rainfall has been found to influence the epidemiology of diseases and their severity i.e. by its effect on

sporulation, dissemination and deposition of spores. Rainfall may also favour the spread of virus diseases, thanks to their effect on insect vectors. In the case of pests, climatological factors are often responsible for variation in biotic potentials in relation to space and time. Hence aberrations in rainfall entailing drought or flood are likely to have an influence on the incidence of diseases and pests, but it is not precisely known to what extent diseases and pests contribute to yield losses under conditions of drought or flood. A few examples may however be cited to illustrare this impact.

In 1942 in Bengal (which then comprised the actual West Bengal of India and Bangladesh) the third week of October was characterized by a fairly widespread rain due to severe depression in the Bay of Bengal. The cyclonic weather was prevalent for 2-3 days preceeded by cloudy conditions for a couple of days. This cyclonic weather coincided with the period of flowering of the rice plants. The effect resulted in a devastating spread of the brown spot disease caused by *Helminthosporium oryzae* which turned out to be responsible for a thirty three percent yield reduction and thus became one of the major contributory factors to the Bengal famine of 1943 (Report of the Famine Enquiry Commission of the Bengal Famine, 1943 ; Padmanabhan, 1973).

In West Bengal in 1981 infection by the Rice Tungro Virus (RTV) was widespread during the main rice growing season (kharif). The disease was severe on both high yielding dwarf *indicas* as well as on tall *indicas* Dasgupta (1988) reported that in some cases loss in yield was as high as sixty percent. This disease, the effect of which was aggravated resulting in partial drought during the later stages of growth, had an adverse effect on total yield as well as on productivity. The total yield of kharif (aman) rice dropped from 6.024 million t. harvested in the previous year to 4.408 million t. and the productivity from 1429 kg/ha to 1045 kg/ha (Anon, 1985). Attacks by the cotton bollworm (*Heliothis* spp.) were aggravated by droughts in 1986 and 1987 and had severe effects on the cotton yield resulting in economic problems for the cotton growers. In a few cases, cotton growers committed even suicide.

The International Rice Research Institute in the Philippines (Anon , 1973) that during wet weather which is favourable for rice growing, grain yield in the field of certain farmers was reduced by 70 percent by diseases and pests The corresponding reduction during the dry season amounted only to 35 percent.

Effect of dry and waterlogged soil on soil borne fungi

A perusal of literature reveals that a few soil-borne diseases are favoured by dry soil, namely seedling blight of cereals, stem rot of sweet potato (*Fusarium solani* f. sp. *batatas*), common scab of potato (*Strepotomyces scabies*). charcoal rot of a large number of crop plants including cotton, sorghum, groundnut, caused by *Macrophomina phaseolina*, root rot of jute due to the same causal agent

Table 2. *Total rice area, percentage of damaged area and the cause of damage in Thailand* (1907-1965)

Year	Cultivated area (10^3 ha)	Harvested area (10^3 ha)	Total field area (%)	Production (10^3)	Remarks
1917	2223	1757	21.0	2989	Flood
1919	2479	1404	43.4	2270	Drought
1928	2722	2386	16.3	3882	Drought
1929	3036	2445	19.5	3875	Drought
1936	3258	2226	31.7	3380	Drought
1942	4379	2876	34.3	3854	Flood
1954	5557	4524	18.6	5709	Drought
1957	5075	4287	15.5	5570	Drought

Source : Israrkura (1966) (Cited from Proceedings of Workshop on Dry land rice, I.R.R.I. 1986)

$$\text{Failed area } \% = \frac{\text{Cultivated area—harvested area}}{\text{Cultivated area}} \times 100$$

M. phaseolina. Its pathogenicity is apparently dependent upon water stress in plants, as shown in a few cases studied namely sorghum and cotton. The disease develops most rapidly and becomes severe when a vigorous crop is subjected to a week of hot weather between bloom and maturity. The combined stresses of blooming and lack of soil water predispose the host plants to attack by the pathogen (Edmunds, 1964).

Each microorganism has optimal and minimal water potentials for growth and plant pathogens are no exception. The simplest explanation for the fact that most root diseases do not occur in dry soil is that the water potential is too low for the growth of pathogens in drier soils This is particularly true for pathogens which are active at or near the soil surface e.g. *Sclerotium rolfsii*.

Though root diseases do normally not occur in dry soil or under drought conditions except in a few cases several of them are controlled under flooded conditions lasting for varying periods of time (Newhall, 1955). The classical example in this respect is the Panama disease or wilt of banana caused by *Fusarium oxysporum* f. sp. *cubense*. In Central America, the intensity of the disease was appreciably reduced by flooding the soil, infested with the pathogen. Special dykes were built to this end. The harmful effect of flooding may be related to lack of oxygen, as most plant pathogens are strong aerobes, increased carbon dioxide concentration or various microbiological changes and interactions (Schippers and Jams, 1979).

Diseases caused by pythiaceous fungi, particularly soil inhabiting species of *Pythium* and *Phytophthora* are definitely aggravated by waterlogged conditions due to heavy rains and flooding. Some diseases may be quite devastating in their effect. Examples may be cited of damping off of seedlings, foot rot of papaya

from seedling to mature stage (*Pythium aphanidermatum*), rhizome rot of ginger and turmeric caused by different species of *Pythium*, foot rot of betelvine (*Piper betle*) caused by *Phytophthora nicotianae* f.sp. *parasitica* and *Phytophthora palmivora*. Waterlogged conditions results in the presence of free moisture in the soil which favours the formation of zoosporangia, liberation of zoospores and their dispersal. After an extensive flood in September, 1986 in the Midnapur district of West Bengal (India) extensive damage secured to betelvine plantations to the extent of total loss. Infection due to gummosis of citrus caused by *Phytophthora citrophora* is easily spread in flood affected areas (Chattopadhyay, 1967).

Table 3. *Productivity of winter rice (Aman) in different years in West Bengal*

Year	Condition of the year	Productivity (kg/ha)
1951-52	Severe drought	941
1952-53	Drought	994
1953-54	Very good rainfall	1315
1956-57	Normal rainfall	1131
1959-60	Flood	986
1960- 1	Good rainfall	1245
1965-66	Drought	1087
1966-67	Drought	1072
1971-72	Normal rainfall	1185
1972-73	Drought	1052
1973-74	Drought	1081
1975-76	Normal rainfall	1222
1980-81	Good rainfall	1429
1981-82	Drought	1045
1982-83	Severe drought	900
1983-84	Good rainfall	1431

The effect of drought or waterlogging on the incidence of soil borne root diseases may be due to a weakening of the host rather than of the pathogen. Examples may be cited e.g. the guava wilt in West Bengal and other parts of India, which occurs both in dry lateritic tracts as well as waterlogged area in the lower Gangetic plains. The genesis of the disease caused by the pathogens *Macrophomina phaseolina* and *Fusarium solani* is related to the damage suffered by the root system, particularly by the young rootlets as a consequence of drought in dry lateritic zones In case of severe waterlogging due to flooding the rootlets die due to anaerobiosis, similar effects are observed. The damage to root system in either case enables the pathogens to colonize the damaged or dead roots eventually leading to a parasitic invasion (Chattopadhyay and Bhattacharjya, 1967).

Table 4. *Productivity of sugarcane in different years in West Bengal*

Year	Condition of the year	Productivity (kg/ha)
1959-60	Flood	39,825
1965-66	Drought	45,600
1966-67	Drought	41,108
1977-78	Good rainfall	60,726
1979-80	Drought	49,051
1980-81	Good rainfall	60,566
1982-83	Drought	51,403

A similar situation is noticed in case of wilt of sugarcane caused by *Cephalosporium sacchari*. The pathogen is normally a weak parasite. The disease does not cause any serious damage under normal conditions. When the sugarcane crop is damaged due to water logging caused by flood in Gangetic belt, it becomes predisposed to attacks by the pathogen and the disease may cause extensive losses.

Regarding wilt diseases caused by typical vascular parasites such as *Fusarium* spp, the effect of drought and flood has not been found to be consistent. To cite a few examples, wilt of flax caused by *Fusarium oxysporum* f. sp *lini* (Maity *et al.* 1988) is favoured under drier conditions of the soil due to drought. For the Panama disease of banana caused by *Fusarium oxysporum* f. sp. *cubense* flooding helps to get rid of the soil-borne pathogen. Wilt of castor (*Ricinus communis*) caused by *Fusarium oxysporum* f sp. *ricini* and wilt of safflower caused by *Fusarium oxysporum* f. sp. *carthami* are favoured under waterlogged conditions (Maity *et al.* 1988). In respect to many other wilt diseases caused by *Fusarium* spp., moderate soil moisture has been found to favour the disease (Maity *et al.*, 1988).

Effect of drought and heavy rainfall on foliar diseases

Attacks by foliar pathogens are normally favoured by heavy and prolonged rainfall and high relative humidity. There are however a few instances where drought entailing a lack of available soil moisture predispose the plants to attack by a few pathogens. Examples may be cited of brown spot of rice caused by *Helminthosporium oryzae* where conditions of drought do not favour a healthy growth of plants and render them more susceptible to attacks by the pathogen. This observation was made in 1952 when a fairly severe drought occurred in the dry belt of West Bengal. If the soil moisture is deficient, the silicification of epidermal cells of rice leaves is hampered and the leaves lose their protective device against faliar diseases and as a result blast caused by *Pyricularia oryzae* and brown spot by *Helminthosporium oryzae* are encouraged.

Aerial blight of soybean (*Thanatophorus cucumeris*) is prevalent in areas of heavy rainfall resulting in temporary waterlogging as it happens in the Tarai region of

Uttar Pradesh and the North Eastern States of India. Sunflower downy mildew (*Plasmopara helianthi*), leaf spot of flax (*Alternaria lini*), leaf spot of castor (*Alternaria ricini*), leaf spot of sesame *(Alternaria sesami*), leaf spot of groundnut (*Cercospora arachidicola*, *Phaeoisariopsis personata*) amongst many others are favoured by rainfall and waterlogged conditions of the soil (Maity *et al.*, 1988).

Effect of drought on bacterial diseases

Diseases caused by bacterial pathogens are normally favoured under conditions of high rainfall and high relative humidity, as these conditions are neccessary for the establishment of infection, multiplication and spread. Notable exceptions are *Streptomyces scabies* causing scab of potato, *Xanthomonas campestris* pv. *oryzicola* causing Bacterial Leaf Streak (BLS) of rice. Bacterial Leaf Blight of rice (BLB) (*Xanthomonas campestris* pv. *oryzae*), Bacterial Leaf Blight of mustard (*Xanthomonas campestris* pv. *campestris*), Bacterial Leaf Blight of sesame (*Pseudomonas sesami*), Bacterial pustule of soybean (*Xanthomonas ampelina*), Bacterial Leaf Spot of castor (*Xanthomonas ricinicola*) ; they are amongst many others favoured by wet soil and high rainfall (Srivastava and Patel, 1978; Maity *et al.* 1988).

Effect of drought and wetness of soil on plant parasitic nematodes

As far as nematodes are concerned, different effects have been observed. Extreme soil water conditions do not favour the occurrence of nematodes. Some nematodes such as *Dolichodoms*, *Radopholus*, *Hemicycliophora* and *Hirschmaniella* are chiefly found in wet locations and can live and thrive in saturated soils. The incidence of the Ufra disease of rice caused by *Ditylenchus augustus* an ectoparasitie nematode (particularly on glumes) is definitely favoured by perpetually moist or wet conditions of the soil.

On the other hand, drier conditions of the soil favour and flooding reduces the occurrence of *Meloidogyme*, *Heterodora*, *Prateylenchus*, *Tylenchorhyncus*, (Reddy, 1983). *Tylenchorhyncus brevilineatus* causing the Kalahasti malady of groundnut is favoured by drier conditions of the soil, resulting in a moisture deficit(Maity *et al.* 1988). In the Tarai region (foot hills of the Himalayas) root knot caused to upland rice by *Meloidogyne* spp. is serious when drought prevails and is reduced when heavy rainfall occurs. They are virtually absent in wet puddled rice soil. Assosciation of *Meloidogyne* spp. with *Macrophomina phaseolina* is noticed under conditions of moisture deficit of the soil. *Radopholus similis*, the burrowing nematode of banana rhizomes is often serious under waterlogged conditions which may occur due to defective drainage or flooding.

Effect of drought and flood on the incidence of insect pests

As far as insect pests are concerned, two different situations have been noticed.

Drought or dry conditions of the soil favouring attacks termites (*Microtermes* spp,

Odontotermes spp, including *O. opesus*, *Macrotermes* spp.), grubs (*Holotricha consanguinea*, *Holotricha insularis*, *Anomala bengalensis*); mole cricket (*Gyralotalpa* spp.); various types of borers including rice stem borers (*Sesamia calamitis*, *Chilo partellus*, *Maliarpha separetella*); sugarcane borers (*Diatraea saccharalis*, *Castinia licoides*, *Emmalocera depressella*; *Chilotraea infuscatellus*); groundnut borer—*Sphenoptera perotelli* ; maize and jowar borer *Chilopartellus*. Flooding rice fields has been found to have a supressive effect on borers.

Thrips are often abundunt under drier conditions. These include groundnut thrips *Caliothrips indicus*, onion and cotton thrips—*Thrips tabaci*, Chilli thrips *Scirothrips dorsalis*.

Arachnids as a whole are favoured when drought prevails or atmospheric humidity is low and the ambient temperature high. Notable among them are the red spider mite *Tetranychus cinnabarinus* attacking a number of host plants; yellow mite of jute *Potyphagus tarsonemus latus*; tea red mite *Oligonychus theae*, rice mite *Oligonychus oryzae*. Heavy rainfall has been found to reduce the incidenee of mites.

In respect to pests occurring on rice, a number of them have been found to thrive and cause substantial damage under conditions of drought. These include rice *Hispa armigera* in North East India and Bangladesh; leaf folder (*Cnaphalocrocis medinalis*); bugs (*Heptocorisa spp*); rice thrips (*Thrips oryzae*, *Haplothrips aculeatus*), besides some borers already mentioned. Paddy pests that do not at all thrive under conditions of drought include: gall midge (*Orseolina oryzae*), case worm (*Nymphula depunctalis*), leaf roller (*Susumia exigua*); brown plant hopper (*Nilaparvata lugens*). These are favoured under conditions of high relative humidity and high rainfall. In years of drought in 1982 and 1985 damage due to rice hispa was quite serious.

Cotton boll worms (*Heliothis* spp. were very devastating in drought affected areas in 1986 and 1987 with serious effects on the economy of growers. The soybean leaf roller (*Lamprosema indicata*) is favoured under water logged conditions.

Mechanical transmission of pests due to flood

Heavy rains accompanied by flooding often result in mechanical transportation of insect pests. Larvae of the swarming caterpillar *Spodoptera mauritia* and *S. littaralis* have been found to be transported into rice fields in the lower situations from glasslands in upper situations in the Tarai region (foot hills of the Himalayas) in West Bengal. Seeds of the root parasites *Orobanche* spp. have been found to be transported into new flood prone areas following flood and the parasite has been found to establish itself on a number of host plants.

CONCLUSIONS

The data presented above are not exhaustive in the sense that they do not constitute the summary of informations that might be available in different parts

of the world, but they are quite indicative. Both drought and flood have been found to have an impact on the incidence of pests and diseases. In a few cases, pests and diseases coupled with adverse weather conditions have been found to be responsible for drastic reductions in yield.

Data on the effect of drought and flood on the incidence of diseases and pests and accordingly on yield or productivity are insufficient. Reasons for this are lack of precise studies in the field, inadequate field observations and lack of proper analysis of the data however meager they may be.

It is suggested that studies on the effect of agrometeorological factors on the incidence of diseases and pests be intensified in two directions. Firstly studies should be undertaken under controlled conditions in the laboratory and glass or green houses where appropriate facilities would be provided to simulate weather observations including drought and flooding. Secondly there should be extensive field studies on the incidence of diseases and pests, particularly in years of aberrant rainfall in order to establish a correlation between meteorological factors including drought or waterlogged conditions of the field and the incidence of diseases and pests and their possible role on productivity under such conditions.

Based on such studies, a sound warning system has to be gradually provided indicating the possible aggravation of specific diseases and pests particularly where forecasts on aberrations in monsoon rainfall can be made by meteorological organizations.

Besides studies should be initiated on post flood conditions since the appearance of any disease or pest following flood may have a quite unexpected impact on either the crop having survived or the following crop. The example may be cited of Rice Tungro Virus RTV) on summer boro) crop of rice in some areas in West Bengal following the September—October, 1978 flood.

SUMMARY

Data collected over the years on the effect of drought and flood on yield and productivity of rice and sugarcane show that both drought and flood adversely affect productivity and total yield.

The role of diseases and pests in relation to drought and flood in bringing down production or productivity of crops has not been determined. Three examples have been cited in India which indicate the possible role of diseases and pests under aberrant weather conditions bringing about reduction in yield, namely the brown spot of rice in 1942 : Rice Tungro Virus in 1981 ; and cotton bollworm in 1986 and 1987.

A number of diseases are favoured under dry conditions of the soil, the most important being charcoal rot caused by *Macrophomina phaseolina* which affects a number of crops.

Rot caused by pythiaceous fungi, particularly *Pythium* and *Phytophthora* are usually very destructive under wet and waterlogged conditions.

Fusarial wilts show different behaviour. Fusarial wilts of flax is favoured under dry condition of the soil, whereas the Panama disease of banana, *Fusarium oxysporum* f. *cubense*, can be eliminated by flooding the soil. Fusarial wilt of safflower, and castor is prevalent under wet soil conditions.

Brown spot of rice and blast are prevalent and more severe under deficient soil moisture conditions affecting growth. On the other hand aerial blights caused by *Alternaria* spp. and a few other pathogens are more destructive under conditions of heavy rainfall and waterlogging.

Bacterial diseases are favoured under conditions of heavy and continuous rainfall, notable exceptions being the common scab of potato and the Bacterial Leaf Streak of rice.

Some nematodes such as *Dolichodoms*, *Radopholus*, *Hemicycliophora* and *Hirschmaniella* are chiefly found in wet locations and can live and thrive in saturated soil. Drier conditions of the soil favour and flooding reduces the occurrence of *Meliodogyne*, *Heterodera*, *Pratylenchus* and *Tylenchorhyncus*.

Drought or dry conditions of the soil favour attacks by termites. grubs, mole crickets, various types of borers, thrips and arachnid pests

A few paddy pests, namely rice hispa, rice mealy bugs, bugs, leaf folders. thrips thrive under dry conditions, whereas gall midges, caseworms, leaf rollers and brown plant hoppers are favoured under conditions of high humidity and rainfall. The cotton bollworm has been devastating in drought affected areas in India, but the Soybean leaf roller thrives under waterlogged conditions.

Flood water has been found to be involved in mechanical transport of swarming caterpillars of rice and the root parasite Orobanche, a parasitic plant.

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