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ADVANCES IN PEST AND DISEASE MANAGEMENT OF RICE IN SRI LANKA: A REVIEW

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INTRODUCTION

With the increasing awareness of detrimental effects of chemical-based pest and disease management on natural control mechanisms, environment and human health, research efforts were directed towards the development of environment-friendly pest/ disease management strategies and dissemination of such technologies to farmers in Sri Lanka. In this context, while continuing the emphasis placed on breeding new rice varieties with durable resistance to major pests and diseases research, efforts were made on habitat-centered concepts to broaden existing knowledge on pest management. These research and development efforts were instrumental in generating knowledge and technologies for effective and efficient pest and disease management in rice.

This paper reviews the present knowledge on insect pests and diseases of rice in Sri Lanka and the improvements made on their management during the last decade. It also proposes directions for future research in the development of sustainable pest/ disease management methods to increase rice productivity and profitability and to conserve the environment.

INSECT PEST MANAGEMENT

Major pests of rice

Rice thrips (*Stenchaetothrips biformis*), gall midge (*Orseolia oryzae*), leaffolders (*Cnaphalocrocis medinalis* and *Marasmia* spp.), yellow stem borer (*Scirpophaga incertulas*), brown planthhopper (*Nilaparvata lugens*) and paddy bug (*Leptocorisa oratorius*) are considered as major pests of rice in Sri Lanka (table 1). Available information on the severity of damage and frequency of occurrence are considered in selecting these insects as major pests of rice (Kudagamage and Nugaliyadde, 1995). In addition, incidences of white-backed planthopper (*Sogatella furcifera*), cut-worm (*Spodoptera* spp), ear cutting caterpillar (*Mythimna separata*), black bug (*Scotinophara lurida*), mites (*Stenotarsonemus spinki* Smiley), nematode (*Meloidogyne graminicola*) and rat (*Bandicota bengalensis*) damages are emerging frequent field problems from various locations through out the country during the past decade.

Table 1. Estimated area affected and extent damage by insect- and other pests of rice in Sri Lanka.

Pest	*Area affected (%)*	*Estimated yield loss (as a % of the potential yield in the affected areas)*
Major pests		
Rice thrips	10	5 – 20
Rice gall midge	10	10 – 20
Leaf folders	20	5 – 25
Yellow Stemborer	2	1- 5
Brown planthopper	1 - 5	10- 50
Paddy bug	20	5- 60
Minor pests		
Cut worms	< 0.1	5
Rats	< 0.1	5-30
Mites	<5	Not estimated
Black bug	2	Not estimated
White-backed planthopper	< 0.1	1- 5

Host-plant resistance to thrips, gall midge and brown planthopper

a). Breeding for pest resistance

The breeding program to incorporate resistance for thrips (TH), gall midge biotype II (GM II) and brown planthopper (BPH) resistance into new improved varieties was continued. Five new-improved varieties with multiple resistance to GM II and BPH and 3 varieties with resistance for BPH alone were released for commercial cultivation during the last decade (table 2).

Table 2. Levels of resistance to BPH and GM II of the new improved varieties released from 1990 – 2000

Variety	*Year released*	*Resistance to*	
		BPH	*GM II*
Bg 304	1993	MR	R
Bg 305	1999	MR	R
Bg 352	1996	MR	S
Bg 357	1997	MR	R
Bg 358	1999	MR	S
Bg 359	1999	MR	R
Bg 360	1999	MR/MS	R
Bg 405	1997	MR	S

S= susceptible, R = resistance, MR = moderately resistance

The breeding program for TH resistance was not successful. Complicated nature of the factors associated with TH resistance in traditional donor varieties like Dahanala and the incompatibility, indicated in the form of grain-sterility, in crosses between the donors and new improved varieities made breeding for TH resistance complex and difficult (Kudagamage and Nugaliyadde, 1995). However, the breeding program for TH resistance using ARC 13761 (which differs from Dahanala) as the donor is in progress.

The breeding program for GM II resistance, initiated in 1986, was able to develop only 5 varieties (Bg 304, Bg 305 and Bg 357, Bg 359, Bg 360) possessing resistance to the pest. Since no new sources of resistance to GM II were found, use of resistant genes originating from Ptb 18 and Ptb 21 were continued (Nugaliyadde, 1996). The progress of the incorporation of GM II resistance which is recessive in nature is rather slow (Gunadasa *et al.*, 2000) as compared to the incorporation of GM I resistance which is dominant in nature (Kudagamage and Nugaliyadde, 1995). Therefore preliminary steps have been taken to develop marker aided selection program to enhance breeding for GM II resistance.

Table 2. Levels of resistance to BPH and GM II of the new improved varieties released from 1990 – 2000.

Variety	*Year released*	*Resistance to* *BPH*	*GM II*
Bg 304	1993	MR	R
Bg 305	1999	MR	R
Bg 352	1996	MR	S
Bg 357	1997	MR	R
Bg 358	1999	MR	S
Bg 359	1999	MR	R
Bg 360	1999	MR/MS	R
Bg 405	1997	MR	S

S= susceptible, R = resistance, MR = moderately resistance

The breeding program for BPH resistance, initiated in 1974 continued to use Ptb 33 (or its derived lines) as the donor parent. The high level of resistance to BPH and its compatibility as a donor variety could be accounted for the extensive exploitation of Ptb 33 as a donor parent. BPH resistance in Ptb 33 found to be controlled by a polygenic system with at least one major gene and several minor genes (Nugaliyadde and Samanmalee, unpublished). The chemical composition of the surface lipids and phloem amino acids found to be associated with BPH resistance in Ptb 33 (Nugaliyadde, 1994). Investigation of BPH resistance mechanism of Bg 379-2 and Bg 300 revealed that the resistance in Bg 379-2 is due to the amino acid composition of the phloem sap as compared to the resistance in Bg 300 which is due to the surface lipid composition (Nugaliyadde, 1994). These results indicated that the BPH resistance in the above varieties is independently inherited. Efforts are now being made to transfer BPH resistance genes from IR 543451, which derive its resistance characters from a wild rice, *Oryza australiensis.*

b). Factors associated with resistance to BPH

Instability of the varietal resistance due to the rapid adaptation of pests to previously resistant varieties (Heinrichs and Pathak, 1982) requiring continued replacements with different resistant bases is a major challenge to the national rice improvement programs in Asian countries. In this context, more attention has been given on BPH and GM where biotype development is known to occur more frequently. As an initial step, studies were undertaken to describe factors responsible for BPH resistance in rice to help improve plant-resistance to the insect and to search alternate strategies for BPH management (Cook *et al.*, 1987; Woodhead and Padgham, 1988; Nugaliyadde, 1994). Such information would be used to design rotational cultivation of different varieties and in synthesis of biologically active compounds for insect management.

Experiments conducted showed that the composition of surface lipids is responsible for BPH resistance in the donor parent Ptb 33 and one of its derived variety, Bg 300. The resistant (R) variety Ptb 33 had more surface lipids (0.25% fresh weight) than moderately resistant (MR) Bg 300 (0.16%) and Bg 379-2 (0.1%) and susceptible (S) Bg 380 (0.07%) and TN1 (0.08%) (Nugaliyadde, 1994). On Bg 380, TN 1 and Bg 379-2, BPH moved less and spent more time on feeding than on Ptb 33 and Bg 300. Movement and feeding time of BPH on surface–washed (dewaxed) Ptb 33 and Bg 300 were less than they did on Bg 379-2 and TN1 (S variety). The insect gained more weight and excreted more honeydew on surface-washed Ptb33 and Bg 300 and did vice versa on TN 1 and Bg 379-2.

The amino acid composition of the phloem sap of Bg 379-2 found to be similar to that of the resistant donor Ptb 33. However, the amino acid composition of Bg 300 differed from Ptb 33 (table 3). BPH fed less on sugar medium containing phloem exudates of Bg 379-2 and Ptb33 as compared to Bg 300 and TN1. These observations indicated that phloem amino acid composition is responsible for BPH resistance in Bg 379-2 (table 4).

Table 3. Relative contents of amino acids in leaf sheath exudates of rice.

*Amino acids**	*Ptb 33*	*Bg 300*	*Bg 379-2*	*TN1*
Alanin	4	2	5	6
Aspartic acid	18	16	17	15
Arginine	2	3	2	3
Asparagine	6	5	7	6
Glutamine	17	11	18	10
Glutamic acid	12	8	13	5
Serine	11	4	14	6
Threonine	5	6	7	5
Valine	6	4	5	4

*Only important amino acids are indicated

Table 4. Amount of food ingested by BPH on sugar solution treated with phloem exudates.

Variety/ exudate	*Amount of food ingested (ug/d/female)*
Ptb 33	2.1 a
Bg 300	3.1 b
Bg 379-2	1.9 a
TN1	4.2 c

Means followed by a common letter are not significantly different at 5% level by DMRT

c). Inheritance of GM and BPH resistance in rice.

The studies undertaken to determine the inheritance of RGM and BPH helped to design breeding and selection methods. GM II resistance in Ptb 21/ Ptb 18 found to be controlled by one or two recessive genes (Gunadasa *et al.*, 2000). As such selection of segregating populations were designed accordingly. The polygenic nature of BPH resistance in Ptb 33 supported the findings of the complex nature of interaction between BPH and rice.

d). Biotypes

With the introduction of varieties possessing resistance to BM II an investigation was conducted to determine the variations of GM populations within the country from 1994 – 95. The GM populations from different parts of the country reacted similarly to the differential set of varieties used indicating no variation of GM population within the locations tested (Nugaliyadde, 1996). However, Katiyar *et al.*, (2000) using ALFP technique showed a variation between the GM populations from Batalagoda and Bombuwela and indicated that these two populations as separate biotypes.

Natural enemies of rice pests

a). Natural enemies of paddy bug

Gryon nixoni was found to be the predominant egg parasitoid of paddy bug in Sri Lanka (Nugaliyadde and Edirisinghe, 2000). Egg masses were collected from Batalagoda, Polonnaruwa, Matale and Gampaha over a period of two years to identify merging parasitoides in the laboratory. Of the 1544 egg masses collected 212 (13.7%) were found to be parasitised by *G nixoni* (table 5). A total of 914 parasites emerged from the 20,072 eggs in all egg masses collected thus giving an over all egg parasitism level of 4.5%.

Table 5. Number of egg masses collected and the eggs found to be parasitised by *G. nixoni*.

Location	*Season*	*Egg masses collected*	*Total eggs observed*	*No. egg masses parasitised*	*Total no. eggs in parasitesed egg masses*	*No eggs parasitised*
Batalagoda	1996/97 *maha*	251	4350	36	401	228
	1997 *yala*	451	5169	81	911	356
	1997/98 *maha*	78	872	6	54	27
	1998 *yala*	134	1589	14	123	51
Polonnaruwa	1996/97 *maha*	56	761	4	36	14
	1997 *yala*	87	967	13	111	41
	1997/98 *maha*	145	2004	21	178	64
	1998 *yala*	132	1765	18	167	59
Matale	1996/97 *maha*	34	436	3	12	16
	1997 *yala*	57	674	7	54	35
Gampaha	1996/97 *maha*	78	907	4	31	19
	1997 *yala*	41	578	5	72	4
Total		1544	20072	212	2151	914

G. nixoni found to prefer 1-2 day old paddy bug eggs for egg laying under laboratory conditions. Paddy bug eggs with different maturity was exposed to the parasitoid under laboratory conditions. The parasitism reached as high as 78% on 1-2 day old host eggs (table 6). Furthermore, the parasitoid was found to reject mature host-eggs (> 3 day old) for egg laying.

Table 6. Influence of the maturity of paddy bug eggs on egg laying preference of *G. nixoni*.

Maturity of the egg mass (d)	*No. egg masses exposed*	*Total eggs exposed*	*No eggs parasitised*	*% parasitism*
1	42	462	359	78
2	12	143	107	75
3	26	298	23	7.6
4	6	74	0	0
5	32	375	0	0

These observations indicated that egg parasitism of paddy bug is very low under natural conditions. This could be attributed to the effects of pesticides on the population levels of the parasitoids.

b). Natural enemies of rice gall midge

Collaborative studies with the Tropical Agriculture Research Center, Japan (presently Japan International Research Centre for Agricultural Sciences- JIRCAS) on natural enemies of GM helped further improve our knowledge on the natural enemies of the pest (Kobayashi *et al.*, 1990. Kobayashi *et al.*, 1991; Kobayashi *et al.*, 1995; Kudagamage and Nugaliyadde, 1995).

These studies revealed that the GM parasitoids could survive on rice ratoon. While *Platigaster oryzae* and *P. foerstery* could pass through the off season in the form of pupa, other parasitoids (*Euritoma* sp. *obtusiclava oryzae*) survive in the form of larvae. Furthermore larvae of *Ophionea indica* was identified as a predominant predator of GM larvae and pupa in Sri Lanka. In the wet zone districts the larval density reached as high as 12%. These observations further supported the rich diversity of natural enemies of rice gall midge in Sri Lanka.

Pest ecology

a). Population dynamics of paddy bug

Studies were undertaken to stop-gap the available information on ecology and biology of paddy bug (Nugaliyadde and Edirisinghe, 2000). Regular sampling of arthropod communities in and around rice ecosystems in Batalagoda, Polonnaruwa, matale and Gampaha were done for a period of two years (1996-1998) to study the populations of paddy bug on rice and weeds, and parasites and predators of the pest.

A regular seasonal variation was observed for paddy bug population at Batalagoda, Polonnaruwa, Matale and Gampaha. The peak populations synchronized with crop heading through harvesting in *maha* (November-March) and *yala* (June – August) seasons.

At Ukuwela fields in Matale rice is grown mainly during *maha* season (September–February) and the *yala* season (April-August) cultivation is confined to a limited area. During the sampling period (December 1996 – February 1998), paddy bug populations were very high in *maha* compared to *yala*. Limited availability of rice during *yala* could have been the main limiting factor for the multiplication of the insect during the season. Paddy bug populations at Gampaha were very low and confined to the rice growing *maha* season (September– February). During the off-season and *yala*, paddy bugs were not recorded in the area. Therefore in the absence of resident populations, the insects infested the *maha* crop would have migrated from other areas. Therefore, it is evident that field populations of paddy bug could be composed of both migrating and resident populations.

A close relationship was observed between population densities of paddy bugs on rice and weeds. The peak insect densities in rice and weeds were respectively recorded at heading-milky stage and at harvesting of rice. This could be related to the phenology of rice and weeds in the sampling locations and to the insect's behaviour to aggregate on rice at heading for feeding and oviposition and to migrate to weed flowers in the absence of rice flowers. Most weeds in rice and non-rice areas start to flower before rice heads and continue until the weeds dry off. This makes continuous availability of weed flowers for the survival of paddy bug.

Paddy bugs were not found in the samples collected from the natural vegetation and weedy areas in Matale and Gampaha during the off-season. This is in spite of the availability of alternate weed hosts in these locations. These observations indicated the insect's ability to migrate into distant habitats once the crop is harvested.

b). Population structure of paddy bug

While the young nymphs (first, second and third instars) were confined mainly to rice the mature nymphs (the forth and fifth instars) were detected on rice and on weeds soon after rice was harvested. Young nymphs were not detected in the sweep net samples collected from weeds at Batalagoda. Populations of young and mature nymphs collected from rice and weeds showed a gradual succession through out the sampling period. These findings confirmed that paddy bugs lay eggs only on rice, and the young nymphs are unable to migrate and survive on weeds. Paddy bugs lay egg at heading – milky stage of rice to enable all nymphs to mature before the crop harvest. Similar population patterns were observed for those collected in other locations.

c). Maturity of paddy bug

Based on the maturity of eggs the females were grouped into mature and immature. Females bearing > 25 % mature eggs classified as mature ones. Females with immature eggs or <25% mature eggs grouped as immature females. With the assumption that paddy bugs in a given location represent one population, the composition of mature females for a given location was estimated as a percentage of the total females collected in one sampling date.

The percentage of mature females varied from 5% to 95% in all the samples collected. Populations collected from heading through milky stage of rice had more than 40% mature females in them.

In all sampling locations the percentage of mature females increased abruptly with the onset of flowering stage of rice. Therefore, it is possible that the insect has a strong response to the rice plant's allelochemicals composition at heading for ovarial development.

The role of non-rice habitat for rice bug population maintenance, the importance of controlling flowering weeds during the vegetative stage of rice and the importance of paddy bug control before heading were some of the information generated.

Safer insecticide recommendations

Laboratory bioefficacy testing and field evaluations were undertaken to identify safer insecticides, application techniques for rice pests. The criteria used in selecting insecticides for testing were their low toxicity, low dosages and pest specificity. A number of new insecticides and formulations were recommended for rice pest during the last decade (table 6)

Table 6. New insecticides recommended for rice pests.

Insecticide/ WHO toxicity class	*Pest*
Imidacloprid (111)	Thrips, Brown planthopper
Fipronil (11)	Thrips, Brown planthopper , Gall midge, leaffolder
Tebufenozide IV	Leaffolder
Acetaprimid III	Brown planthopper
Azadiractin -	Leaffolder

Furthermore, studies were undertaken to assess the toxicity levels of the commonly used insecticides on major pests. The values obtain would be useful in future revisions of insecticide recommendations (table 8). The acceptability of the new insecticides was evident by the fact those had low Ld 50 values on tested pests.

Table 8. Ld 50 values of insecticides on Brown planthopper (BPH), leaffolder (LF), and Paddy bug.

Insecticide	*BPH*	*LF*	*Paddy bug*
Imidacloprid	0.1	-	0.5
Acetamiprid	1.1	-	4
Carbosulfan	5	19	5
BPMC	9	21	14
Chlopyrifos	17	23	22
Undane	15	14	13
Fenthion	11	15	17

It is proposed that the toxicity levels of insecticides on pests should be monitored on a regular basis to identify the development of insecticide-resistance in pests. Such system also would help update pesticide-recommendations on the basis of their effectiveness.

PEST MANAGEMENT PRACTICES OF RICE FARMERS IN SRI LANKA

A survey was conducted to assess the pest management practices of rice farmers in Sri Lanka. This study was undertaken as a part of a collaborative study between IRRI and the Department of Agriculture, Sri Lanka. A total of 329 farmers in 7 administrative districts of Sri Lanka were interviewed using a structured questionnaire to determine their pest management practices and knowledge on insect pests and natural enemies. A majority of farmers were owner operators (59%) and tenants (26%). Most farmers (53%) had 1 - 1.5 ha rice. Although 98% of rice lands are grown to new improved varieties, their pest resistant characters were not known to 90% of the farmers.

During the main season 1995/1996 (October - February) 262 (79%) farmers reported a total of 452 insect infestations. The pest problems according to the order of priority were leaffolder (22%), rice bug (17%), brown planthopper (16%), yellow stem borer (14%), rats (9%), thrips (5%), cut worm (5%), gall midge (4%) and army worm (4%). Of the 262 farmers who reported insect pest problems, 86% have applied insecticides to control the pests, 7% did nothing, 3% used bating and a small proportion of farmers resolved to traditional methods.

A majority of the farmers (92%) believed that leaf--feeding insects cause severe damage to rice and 67% believed that insecticides were needed to control leaf--feeding insects and that spraying should be done (61%) early to avoid severe crop losses. Of the 329 farmers, 225 have made 386 pesticide applications, making the average no of insecticide application per farmer to 1.1. Of these insecticide application 15% were to prevent pest infestations and 83% were to control pests. Of these insecticide applications, 42% and 40% were made at seedling and vegetative stages respectively. The most commonly used insecticides were carbofuran (42), chlorpyrifos (29), phenthoate (28), methamidophos (19), diazinon (13), monocrotophos (19). About 75% pesticide applications were under dosed.

Although 83% of the farmers knew natural enemies of rice pests only 17% knew the role of natural enemies in rice ecosystem. This survey indicated that the Integrated Pest Management programmes in Sri Lanka have influenced rice farmers to a great extent to understand the importance of natural control mechanisms in pest management. However, in order to sustain such knowledge and attitude farmers should be educated to understand the relationships between pest infestation levels and yields. Furthermore, efforts should be made to conduct farmer surveys on a regular basis to evaluate the impact of the Integrated Pest Management Programs and to direct research efforts in order to fill farmer's knowledge gaps.

DEVELOPMENT OF A SURVEILLANCE AND FORECASTING SYSTEM FOR RICE PESTS IN SRI LANKA

A three year (1996-1999) project was undertaken in collaboration with JICA to develop basic knowledge and methodologies to implement a surveillance and forecasting system for rice pests in the country. Weekly sampling of arthropod community in rice was made over two-year period in

16 locations in Polonnaruwa, Kurunagala, Hambantota, Ratnapura, Kandy. Major arthropods species associated with rice were identified and their numbers were recorded. Predominant pests, parasites, and predators and their abundance were estimated. Simplified sampling method to estimate pests/ natural enemies was developed and field tested. It is expected to introduce this system to establish a surveillance and forecasting system for rice in Sri Lanka (T. Hidaka and L. Nugaliyadde unpublished). It is proposed that efforts should be made to establish a surveillance system to develop a data-base on pest occurrence and a forecasting system to predict pest out breaks using weather and other related data.

DISEASE MANAGEMENT

Major rice diseases

Among the rice disease in Sri Lanka, rice blast (*Riricularia oryzae* Cav.) Bacterial leaf blight (*Xanthomonas campestris* pv. *Oryza*) and sheath blight *Rhizoctonia solani* Kuhn) continue to cause significant yield losses depending on varieties grown, environmental conditions during the cropping season, agro-ecological zone and agronomic practices adopted. In addition grain spotting and discoloration, grain sterility, premature senescence of rice crop and yellowing have been frequently reported as important field problems.

Breeding for disease resistance

Presence of pathogenically different physiological races (Wickramasinghe and Dissanayake, 1990) and the nature of reproduction of rice blast pathogen, necessitate to continue the breeding for blast resistance a major breeding objective. A major drawback in breeding for blast resistance is the non-availability of a proper screening technique to detect resistance at adult plant stage. At present selection is based on seedling blast reaction expecting for resistance at adult plant stage. However recent identification of individual genes for conferring resistance to leaf blast and neck blast resistance, may make it possible to use marker aided selection for neck blast resistance in the future. Breeding for bacterial blight resistance is continued with field screening facilities expansion at Agricultural Research Station, Ambalantota.

Grain discoloration

Grain discoloration is mainly caused by a complex of fungal species. Varietal differences have been observed for the occurrence and severity of grain discoloration. Therefore, in the actual breeding program, breeding lines are advanced only if they are free from discolored grains in the field. Studies were done in Polonnaruwa and at Rice Research and Development Institute, Batalagoda to find whether amendment of soil with straw, paddy husk and different level of N, P and K have any effect on grain discoloration severity levels. However, it was revealed that none of the treatments were effective controlling the grain discoloration, indicating its complex nature of occurrence.

Grain sterility

Grain sterility in rice has often been recorded in Sri Lanka, especially in Mid and Up Country regions, during both dry and wet seasons (Gunawardena, 1980). In recent years, this so-called sterility has become a serious problem even in the Low Country Wet Zone.). The term "sterility" is often used loosely to include both unfertilized and partially filled grains without correct distinction (Yoshida, 1981). However, Morita and Dhanapala (1990) studied the problem of rice grain sterility in Sri Lanka making a clear distinction between unfertilized and partially filled grains and reported that although the main cause for sterility was unfilled grains due to the damage of pests and diseases, some samples showed very low percentage of fertility.

In most parts of the Low Country, especially in the dry season, temperature during anthesis of the rice crop is higher that 30^0C. During this period wind is also high making the conditions very favorable for pollen desiccation. Satake and Yoshida (1978) reported high-temperature induced sterility in rice in areas with high temperature and where the rice growing season had changed due to the introduction of modern cultivars. The same authors (Satake and Yoshida, 1977 a, b, 1978) also reported that heading is the stage at which rice plant is most sensitive to high temperature. At 35^0C day and 30^0C night temperatures, grain sterility increases as a result of comparatively smaller pollens and non-dehiscence of anthers (Sato *et al.*, 1973).

Although sterility in rice in the dry season appeared to be associated with high temperature coupled with high winds at heading time of the crop, sterility in rice in the Low Country Wet Zone may be attributed to low night temperatures during the reproductive growth phase (Jayawardena and Peries, 1980). Satake and Hayase (1970) reported that the most sensitive stage for low temperature is the young microspore stage after meotic division (about 10-12 days before heading) and Nishiyama *et al.*, (1969) reported that critical low temperature for inducing sterility is 17^0-19^0C for the cold sensitive cultivars. In the Low country Wet Season in Sri Lanka, night temperatures less that 19^0C have been recorded.

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