range between 60 m and the elevated layer base height. Wyngaard's approach for estimation of temperature structure and stability characteristic in the ABL using Doppler sodar measured winds and temperature is found to be better in the absence of surface layer and radiosonde measurements. D. K. Paul, S. P. Ghaneskar, B. S. Murthy and K G Vernekar highlighted the sodar observed variations in the vertical wind profile over Kharagpur during passage of synoptic scale disturbances.

In the concluding session P. R. Pisharoty offered his illuminating thoughts about the computation of surface fluxes in the monsoon region and recalled earlier predicaments. The meeting concluded that MONTBLEX '90 has provided valuable and good quality data for atmospheric boundary layer research in the monsoon region. Several new groups have started work on boundary layer studies, with younger scientists coming forward to present the results. D. R. Sikka suggested that the boundary layer research community, which has been generated through MONTBLEX, should make sustained efforts in future too. These efforts should culminate in understanding the unresolved problems of monsoon dynamics

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Biological control programmes in India – A review in retrospect

Professor H. S. Smith coined the term 'Biological Control' in 1919 in reference to the control or regulation of pest populations by natural enemies. Biological control has been in practice since 1200 AD and has provided environmental safety and stability, in addition to profits, to its practitioners. The well-documented introduction of the vedalia lady beetle from Australia to California gave an impetus to biological control. California, Hawaii and Australia were well-benefited from biological control programmes until the advent of World War II. The discovery of chlorinated hydrocarbons during World War II, along with cyclodienes, organophosphates, carbamates, synthetic pyrethrins and others, has subsequently led to the increased use of pesticides and the reduction in utilization of biological control programmes throughout the world. The publication of 'Silent Spring' by Rachel Carson in the early 1960s created a public awareness of the environmental damage that synthetic pesticides can cause. A search for alternative methods to synthetic chemicals led to the re-emergence of biological control. Biological control was rediscovered, not just begun as an 'environmentally safe alternative to the chemical means of control'[1].

Various biological control projects that have been carried out, the benefits derived from them, and problems encountered in different parts of the world have been reviewed and documented[2,3]. Criticism of this programme has been based on fewer facts and some misinformation. Introduction of the vedalia beetle has not only been a huge success but also, thus far, shown no adverse effects. However, a person could conduct a witchhunt to find a minor adverse effect just to discredit this project. In fact, in 1989, the US celebrated by having centenary seminars and workshops to commemorate the introduction of vedalia beetle.

Some authors who wish to discredit biological control repeatedly cite *Teleonemia scrupulosa* Stål introduction to Uganda and India as misjudgements. In Uganda this insect caused annual defoliation of lantana and when there was no foliage it moved on to sesame[4]. On sesame, only the first generation developed and not the succeeding ones[5]. Also, it happened to be one of the most preferred cultivars planted at the Research Station when the observations were made[6]. Greathead[6] stated that he has been misquoted (pers. comm) by some authors to support their views and it is time to put an end to this controversy. In 1943, a laboratory culture of *T. scrupulosa* in Dehra Dun, India, was destroyed as it was found to feed on the leaves of teak[7]. However, the culture escaped from the laboratory and spread throughout India[8]. Ironically, a school teacher was even given an award by the late Prime Minister Indira Gandhi for aiding the spread of this natural enemy and controlling lantana bushes. *T. scrupulosa* has never been reported to feed on teak in the field and also it has not been reported as a pest of sesame since 1967 (ref. 5). Now, it is widely used as an effective natural enemy of lantana throughout the world.

The project for introduction of the Mexican beetle, *Zygogramma bicolorata* Pallister, to India was halted after host-specificity testing in the laboratories of Australia and India and field releasing in some parts of India, because the beetle has been observed to feed on sunflower in the field[9,10]. Time will tell whether the scientists who conducted host-specificity tests failed to detect the beetle feeding on sunflower or if this project will become another wasted controversy and resource, like the introduction of *T. scrupulosa*.

The project to replace *Parthenium* with another exotic, invasive, alien weed, *Cassia uniflora* Mill., lacks merit as the superior allelopathic property of one weed is utilized to replace the other[11]. It may lead to the replacement of one devil with another or may end up aiding the spread of a highly allelopathic exotic weed. Since *Cassia* spp are serious weeds in the tropical regions, some research has already been conducted to explore the possibility of controlling them utilizing classical biological control[12].

The introduction of the toad *Bufo marinus* (L.) to Kosrae by the Japanese for poisoning the monitor lizard is a hearsay story[13]. In a subsequent citation of this article, it was stated that the Japanese introduced this toad to Micronesian islands[1]. The fact is that the toad was introduced to Guam (an island in Micronesia) from Hawaii in 1937. It was brought to Guam as a general predator but a few years later the control of the black slug and the initial decline of numbers of monitor lizard were attributed to this toad[14]. During World War II, the Japanese spread the toad to other Micronesian islands. This work carried out by the soldiers and laymen should not merit a place in the evaluation of a programme like biological control.

Another example of misquotation of a correct and published piece of information is on the introduction of *Orthezia insignis* Browne. It has been documented that this insect was accidentally introduced to the Nilgiris from Sri Lanka in 1915 (ref. 15), but it has been cited as a wrong polyphagous insect introduced to India for biological control of lantana[16,17]. This misquoted information has also been used to discredit the programme for biological control of exotic weeds in India[9].

There are only a few success stories of biological control in India. The reason being that most crop pests are native and have attained an equilibrium with their natural enemies. Augmentative releases of native natural enemies might only cause temporary fluctuations in pest populations. For example, the past fifty years of inundative parasite releases for the coconut caterpillar *Opisina arenosella* Walker in southern India has proven ineffective. Inundative release of the egg parasite *Trichogramma* spp. for control of sugarcane borer and other pests has been steadily gaining popularity in India However, *Trichogramma* spp. are being mass-reared on the eggs of *Corcyra cephalonica* (Stainton) in different laboratories. The production of eggs could be considerably increased if *Sitotroga cerealella* (Oliver) is used instead of *C. cephalonica*[18].

Since most pests in India are native, it may be worthwhile to try Hokkanan and Pimentel's suggestion of introducing natural enemies of a pest closely related to the target pest, which is known as 'new association'. This method is based on the ecological principle of negating the tendency of parasites and host evolving to reach some degree of balance and it has the potential of controlling native pests. It has given a success rate of 75% over the 'old associations'[19].

Most of India's exotic insect pests and weeds were introduced without their natural enemies into the new and favourable environment wherein they became serious pests and weeds. Introduction of effective natural enemies from their native areas normally results in successful suppression. This programme is usually identified as classical biological control Suppression of *Opuntia elatior* Miller by *Dactylopius opuntiae Cockerell*, *Eriosoma lanigerum* (Hausm.) by *Aphelinus mali* (Haldeman), *Quadraspidiotus perniciosus* (Comst) by *Prospaltella perniciosis* Tow, and *Aphytis diaspidis* (Howard) before independence, *Heteropsylla cubana* Crawford by *Curinus coeruleus* Mulsant and *Salvinea molesta* Mitchell by *Cyrtobagous salviniae* Calder and Sands have been achieved by adopting classical biological control techniques.

A brief perusal of biological control programmes in India reveals that most of the projects were piggy-backed onto successful projects carried out elsewhere. Most of the introductions of exotic natural enemies in the past were done through the Commonwealth Institute of Biological Control substation in Bangalore. Natural enemies of lantana from Australia and Hawaii, Crofton weed from New Zealand, *S molesta* from Australia and subabul from Hawaii (via Thailand) were obtained based on exploratory work, host-specificity tests, successful field establishment and the resultant publications from these countries.

Thus far, India lacks programmes for identification of exotic pests and weeds that could be easy targets for classical biological control, biological control strategies for native pests[19], monitoring exotic pests and weeds that have already invaded neighbouring countries and could be expected to reach India within the next few years, and the ability to mobilize resources to tackle an exotic weed or pest immediately after identifying its establishment Recent worldwide increase in commerce, tourism and transportation has a direct relationship to the increase in introduction of exotic pests, diseases and weeds. The state of Hawaii alone experiences the introduction of at least one or more major pests and about 20 arthropods every year[20]. Subabul psyllid, serpentine leaf miner and coffee berry borer are some of the serious pests that have been recently introduced to India. Thus far, the action taken was introduction of a natural enemy for subabul psyllid but yet to implement the projects for the other two pests even though very successful biological control projects have been executed for them elsewhere[3,21,22]. In addition, the exotic weeds, *Mikania micrantha* Kunth and *Mimosa invisa* Mart., that have established in north-eastern and southwestern India are easy targets for biological control. Biological control projects for *M invisa* in western Samoa[23], Queensland (Australia)[23] and Pohnpei (N. M. Esguerra, pers. comm), and for *M. micrantha* in the Solomon islands[24] and Malaysia[25] are in progress. The spiralling whitefly, *Aleurodicus dispersus* Russell, which was noted in Hawaii in 1978 (ref. 26), Guam in 1981 (ref. 27), and in the Pacific islands later on, has already moved to the Maldives. Within the next few years, we can expect it to be in India. The natural enemy of *A dispersus* from Fiji has already been obtained and released in the Maldives[28].

Biological control is not a panacea to tackle all the pest problems. However, the benefits of this programme far outweigh the shortcomings of some introductions of natural enemies At present, India is neither a leader nor a follower in the area of biological control. It is merely a casual player in this arena It could carefully scrutinize the ill and beneficial effects of natural enemies introduced elsewhere and consider introduction of the ones that have less or no negative effects. Already FAO has drafted[29] and the South Pacific Commission[30] has come up with guidelines for biological control introductions. India may as well follow one of them by enacting a legislation. This should ensure negation of ill effects of any future introduction of natural enemies

In general, biological control is economical, effective and environmentally safe when implemented properly. Recognizing its importance, especially in the less developed countries, the Australian Centre for International Agricultural Research (ACIAR) has been supporting major biological control programmes in the Pacific and ASEAN countries[3,23,31]. Biological control has a major role to play in the sustained agricultural development in India. Let us not throw the baby with the bath water.

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Ecological impact of insects introduced for biological control of weeds — conflicting interests

Many plants when introduced intentionally or accidentally into new areas become serious weeds. In the absence of natural enemies they multiply faster in the new environment and occur at much greater population densities than they do in their natural habitat In situations where a single alien weed dominates large areas, biological control by introduced natural enemies alone can provide an economic solution[1]. Up to 1980 there were 174 projects to control 101 species of weeds world-wide, of which 68 projects (39%) were considered successful and led to appreciable control of 48 weeds Although a large number of introductions consisting of 171 species of insects, two mites, one nematode and four fungi were made, there has been no scientific misjudgement nor alteration of insect diet[2].

The first recorded success in biological control of a weed was obtained in India when a bug *Dactylopius ceylonicus* (Green), introduced from Brazil in 1795 for production of cochineal dye, spread on *Opuntia vulgaris* and completely destroyed this cactus in central and northern parts of the country[3]. This was not a deliberate attempt as *D ceylonicus* was mistaken for the true cochineal insect *D coccus* Costa. The first major success in a biological control project was achieved during the 1930s in Australia, where 60 million acres of land were cleared of *Opuntia* spp by the insect *Cactoblastis cactorum* (Bergroth)[4] Excellent results have been achieved recently in India in biological control of the floating aquatic weeds water hyacinth (*Eichhornia crassipes*)[5] and the water fern (*Salvinia molesta*)[6].

The crucial point in a programme for the biological control of a weed is to determine whether a candidate agent can be introduced to control a weed without the danger that it may also damage desirable plants One of the apparent shortcomings of biological control of weeds is that the outcome of its action cannot be predicted in advance. Therefore, most countries including India require that potential biocontrol agents are screened to determine beyond all reasonable doubt, that they will not damage any desirable plant, after release in the area where control of the target weed is required

The currently employed procedures in host specificity determination of exotic biological control agents of weeds' have evolved over a period of 75 years based on experience gained during the execution of various biological control programmes worldwide A series of eight international symposia on biological control of weeds, starting from 1969 provided further opportunities for dis-