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REVIEW

STATUS OF BIOLOGICAL CONTROL TRIALS AGAINST *Parthenium hysterophorus* BY *Zygogramma bicolorata* IN INDIA

K.P.JAYANTH
Division of Entomology and Nematology
Indian Institute of Horticultural Research
Hessaraghatta Lake Post
Bangalore 560 089

ABSTRACT

Parthenium hysterophorus, of Neotropical origin, is the most predominant weed of vacant plots, waste lands and pastures in most parts of India. It has been established that growth inhibitors released from this plant to the soil through leaching, exudation of roots and during decay of residues suppress local vegetation and threatens natural diversity. *P.hysterophorus* is also reported to affect agriculture, human health and livestock production in India. As manual, chemical and competitive displacement methods are not practicable, biological control trials were initiated by importation and releases of the chrysomelid beetle *Zygogramma bicolorata*. The insect established readily, after releases were initiated in 1984, and started building up damaging population levels from 1988. Since then it has spread over more than 200,000 sq km area in and around Bangalore, causing large scale defoliation of parthenium and encouraging the growth of vegetation formerly suppressed by this weed. But the insect was noticed to feed on sunflower in a few isolated fields in Karnataka, raising fears of a host shift. However, detailed laboratory and field studies clearly indicated that *Z.bicolorata* is unlikely to become a pest of sunflower. The results of the studies carried out to date indicate that *Z.bicolorata* has the potential to bring about permanent reduction in the density of *P.hysterophorus* in Bangalore and surrounding areas. However, it may be desirable to import additional natural enemies such as the leaf mining moth *Bucculatrix parthenica* and the seed feeding weevil *Smicronyx lutulentus*. Similarly, importation of host- specific plant pathogens such as *Puccinia abrupta* var. *partheniicola*, may also contribute to the successful biological control of this noxious weed throughout India.

KEY WORDS : Biological Control, Weeds, *Parthenium hysterophorus*, *Helianthus annuus*, *Zygogramma bicolorata*

INTRODUCTION

Parthenium hysterophorus L. (Asteraceae) is a native of southern parts of North America, Central America, the West Indies and the central parts of South America. It has accidentally been introduced, over the past five decades, into many tropical and subtropical parts of the globe. The countries where it is currently reported to occur include Australia, China, India, Israel, Madagascar, Mozambique, Nepal, South America and Vietnam (Towers *et al.*, 1977; Joel and Liston, 1986). Noticed for the first time in Pune in 1955 (Rao, 1956), *P.hysterophorus* is now a serious weed of pastures, waste lands and also of agricultural fields, growing under contrasting ecological conditions from sea level to altitudes up to 2000m, in most parts of India (Krishnamurthy *et al.*, 1977).

The alleopathic properties of *P.hysterophorus*, combined with the absence of natural enemies like insects and diseases that keep it under check in its native home, have aided in the rapid spread of the weed. It has been established that growth inhibitors released from this plant to the soil through leaching, exudation of roots and during decay of residues, suppresses local vegetation. The weed is also reported to affect the growth and yield of several plants (Sukhada and Jayachandra, 1979. 1980a, 1980b). If left unchecked, *P.hysterophorus* is likely to affect natural diversity and cause extinction of native flora.

P.hysterophorus is also known to cause health hazards in humans and animals. It flowers profusely and releases large quantities of pollen into the atmosphere. Aerobiological studies have shown that parthenium pollen constituted 66.18 per cent of the total annual pollen catch in the Bangalore atmosphere (Agashe and Abraham,

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1988). An increase in the incidence of nasobronchial allergy has been reported in Bangalore, concomitant with the steady increase in the widespread growth of the weed (Rao *et al.*,1985). The weed is also known to cause dermatitis in man (Towers *et al.*, 1977). It is a threat to livestock as it reduces the availability of fodder in pastures (Vartak, 1968) and affects animal health when ingested (Narasimhan *et al.*, 1980).

Manual and chemical methods are reported to be effective in controlling the weed in agricultural fields (Krishnamurthy *et al.*,1977). However, these methods are neither practicable nor economical in pastures and waste lands, as repeated applications are required. Competitive displacement, using the weed *Cassia uniflora* Mill. (Leguminosae), has been advocated for the control of parthenium in waste lands (Joshi, 1990, 1991). However, the utility of this methods is limited due to lack of specificity and the need to artificially disperse the competitor. As *C.uniflora* is also of Neotropical origin and already spreading naturally in many parts of northern Karnataka (Joshi, 1990), it could prove to be another potentially harmful weed. Besides, replacement of the noxious *P.hysterophorus* by the unpalatable *C.uniflora* will not solve the problems faced by cattle, especially with respect to fodder availability, in grazing lands.

IMPORTATION OF NATURAL ENEMIES

Since *P.hysterophorus* has reportedly entered India in the seed form, along with imported food grains (Vartak, 1968), the natural enemies that keep it under check in its native home were left behind. Although a number of insects attack *P.hysterophorus* in India (Kumar *et al.*, 1979) none of these are host specific. Extensive surveys carried out in Mexico revealed that all parts of the parthenium plant are attacked by a large number of insects (McClay, 1980) and fungal pathogens like *Puccinia abrupta* var. *partheniicola* (Evans, 1987). Therefore, biological control trials were initiated in India by the Indian Institute of Horticultural Research (IIHR) by importing the leaf feeding beetle *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae), the flower feeding weevil *Smicronyx lutulentus* Dietz. (Coleoptera: Curculionidae) and the stem galling moth *Epiblema strenuana* (Walker) (Lepidoptera: Tortricidae).

Among the insects imported, the culture of *S.lutulentus* could not be established as live insects were not recovered from the shipment. Detailed host specificity tests were carried out with *Z.bicolorata* and *E.strenuana*. The laboratory culture of *E.strenuana* was terminated as quarantine studies revealed that it can complete its development on niger (*Guizotia abyssinica*) (Jayanth, 1987a), although it is considered to be a potential natural enemy in Australia (McFadyen, 1985). Detailed host specificity tests carried out in Mexico, Australia and India (McFadyen and McClay, 1981; Jayanth and Nagarkatti, 1987) confirmed that *Z.bicolorata* is incapable of completing its development on any cultivated crops.

BIONOMICS OF *Z.bicolorata*

Adults of *Z.bicolorata*, which measure about 6 mm in length, are off white in colour, with dark brown longitudinal markings on the elytra. They oviposit singly or in clusters of about six eggs, mainly on the ventral leaf surface. The larvae feed on the leaves, drop down and pupate in the soil. Pupation takes place in chambers formed by the larvae 1-3 cm below the soil surface. The egg, larval and pupal periods are completed 4-5, 10-14 and 8-12 days respectively, with a total developmental period of about 23-30 days, depending on the temperature. Laboratory studies showed that mature larvae are incapable of pupating in dry soil. Soil moisture, equivalent to 1.5 mm of rainfall was required for both burrowing in of full grown larvae and emergence of adults from pupal chambers in the soil (Jayanth and Geetha Bali, 1995).

Adult females are generally larger than males and can easily be differentiated by the shape of the last abdominal sternite. The posterior margin in the case of the female is entire, while it is slightly serrated at the tip in the male. The sex ratio was found to favour of females, with only about 30% of the population being constituted by males (Jayanth and Geetha Bali, 1993a).

Z.bicolorata remains active in the field during the rainy season between May and November, completing 5-6 generations under field conditions in Bangalore (Jayanth and Geetha Bali, 1992). They overcome the dry season by entering the soil and remaining under diapause as adults. The insect entered diapause over an extended period of time between July and December in Bangalore, with a peak during October - November. Diapausing adults burrowed into the soil and emerged in May - June, with the commencement of monsoon rains (Jayanth and Geetha Bali, 1993b). Temperature tolerance studies revealed that the insect is capable of breeding at temperatures ranging from 15-35°C, although 20-30°C was the most suitable. These studies also showed that adults diapausing within the soil cannot tolerate continuous exposure to 40 and 45°C for more than 10 days and 21 h., respectively, suggesting that the beetle is unlikely to survive in a state of diapause in parts of the country, where the summer temperatures exceed 45°C (Jayanth and Geetha Bali, 1993c).

Life table studies carried out during 1989-90 indicated that *Z.bicolorata* is an efficient natural enemy of *P.hysterophorus*, with a high biotic potential. The major mortality factor was found to be infertility of eggs and no parasitoids or predators were recorded to attack this insect (Jayanth and Geetha Bali, 1994a). However, since 1993 a tachinid larval parasitoid? *Chaetexorista* sp. was found to cause up to 51.6 per cent mortality of larvae, towards the end of the breeding season of the insect, during September to November. High level of parasitism, later in the breeding season of the beetle is likely to reduce the number of adults entering the soil for diapause and also the starter population of the beetle immediately after commencement of rains during the following year. A low initial population of *Z.bicolorata* is likely to increase the time taken by it to cause defoliation of parthenium weed (Jayanth *et al.*, 1996).

FIELD EVALUATION

Field releases of *Z.bicolorata* were initiated in 1984 after obtaining the permission of the Plant Protection Adviser to Government of India (Jayanth, 1987b). Although the insect established readily, it started building up damaging population levels only from July, 1988, probably after getting acclimatised to local conditions.

Population build up and dispersal

Studies at Bangalore revealed that an insect density of one adult per plant caused skeletonization of leaves within 4-8 weeks, provided this density is achieved early in the rainy season. Low initial population densities only prolonged the time needed to effect defoliation of the weed. It was observed that up to 2000 adults are produced per sq m of parthenium infestation. After defoliation of parthenium in a particular plot, adults were observed to move into the adjoining field. In the absence of healthy plants, they migrated by flight. The adults of *Z.bicolorata* are aided in their dispersal by the prevailing wind. Surface winds over Bangalore have a clear-cut seasonal character, with the westerly components predominating between May and September and the easterly components during November to March (Mani, 1985). Correspondingly, the insect was noticed to migrate mainly towards the east up to September and in a westerly direction during October and early November (Jayanth and Geetha Bali, 1994b).

Z.bicolorata which was present in only 10 ha area during August 1988, was noticed to have spread over 5 sq km area by October of the same year, which increased to 400, 5000, 20,000 and 50,000 sq km by the same period in 1989, 1990, 1991 and 1992 respectively (Jayanth and Ganga Visalakshy, 1994). The beetle is now dispered over more than 200,000 sq km in Karnataka, Tamil Nadu and Andhra Pradesh, causing large scale defoliation. Reports of its establishment and spread have also come in from Jammu, Punjab, Haryana and Madhya Pradesh.

Effect of defoliation on plant growth and multiplication

Defoliation of *P.hysterophorus* due to feeding by adults and larvae of *Z.bicolorata* was found to cause up to 98 per cent reduction in flower production, even though the insect does not feed directly on the flowers (Jayanth and Geetha Bali 1994b). But the early stage larvae congregate and feed on the terminal and axillary buds, thus preventing the emergence of flowers. Once the flowers present on the plants, at the time of defoliation, mature and the seed drop to the ground, no further flowers are added due to the destruction of flower buds.

Parthenium plants are reported to produce an average of 5925.5 inflorescence per plant (Joshi, 1991), which release enormous quantities of pollen (624 million/plant) into the atmosphere (Towers *et al.*, 1977). Defoliation of parthenium in extensive areas in and around Bangalore city has caused an overall reduction in flower production by the weed, which in turn has reduced pollen density in the atmosphere (Dr.S.N.Agashe, 1994, Professor of Botany, Bangalore University, personal communication). This will benefit the people suffering from nasobronchial allergy.

Succession of vegetation

During studies carried out over a period of three years, in an experimental plot at IIHR, 40 different species of plant, including 8 grasses, were observed to grow in the areas vacated by parthenium, due to defoliation by *Z.bicolorata* (Jayanth and Ganga Visalakshy, 1996). These studies also indicated that the rate of reduction of parthenium infestation and the degree of diversity of succeeding plant species may vary depending on the nature of human intervention, duration of weed occupation, presence of viable seeds of the weed and also that of competing vegetation besides the history of land utilisation. A change in the plant species complex is evident in Bangalore and surrounding areas, with a large number of plants growing in areas which were fully under parthenium cover. Although pure stands of parthenium are still visible at many pockets, these are generally disturbed areas. Field studies also showed that ploughing of fallow agricultural fields, after defoliation of parthenium by *Z.bicolorata*, resulted in renewed weed growth (Jayanth and Ganga Visalakshy, 1996). This may be due to the presence of over 200,000 viable seeds of parthenium per sq m of infested soil (Joshi, 1990).

CONTROVERSY DUE TO FEEDING ON SUNFLOWER

One of the apparent shortcomings of biological control of weeds, using insects, is that it is difficult to predict whether an insect introduced for biological control of weeds may also damage desirable plants. Therefore, it is mandatory that potential biocontrol agents are screened for their specificity to determine, beyond any reasonable doubt, that they will not damage any desirable plant species. Host specificity tests are carried out by following an internationally recognised protocol, which has evolved over a period of 75 years, based on experience gained during the execution of various biological control programmes worldwide.

Although detailed host specificity tests carried out with *Z.bicolorata* conclusively proved its specificity to cultivated plants, the insect was noticed to feed on sunflower in a few isolated fields at Kolar and Arsikere in Karnataka, raising questions about the validity of the above tests and also fears of host plant shift (Kumar, 1992; Chakravarthy and Bhat, 1994). It was also suggested that IIHR had imported *Z.conjuncta* (Rogers), believing it to be *Z.bicolorata* (Chakravarthy *et al.*, 1994).

With regard to the identity, IIHR obtained a culture of *Z.bicolorata* from the Mexican Sub-station of the Commonwealth Institute of Biological Control (CIBC), located at Monterry. The genus *Zygogramma* is endemic to the neotropical and nearctic regions of the world. *Z.conjuncta* is reported only from Canada, where it feeds on poverty weed, *Iva axillaris* Pursh. (Best, 1963). The culture of *Z.bicolorata* introduced into India and Australia was collected from Monterry, Mexico. The material collected was compared with the holotype of *Z.bicolorata* in the American Museum of Natural History, New York. This identification was further confirmed by Dr.Richard White of the USDA Systematic Entomology Laboratory [Dr.A.S.McClay, 1992, Alberta Environmental Centre, Bag 4000, Vegreville, Alberta, Canada (former Head of CIBC Mexican Sub-station) - personal communication].

Both *P.hysterophorus* and *H.annuus* are of Mexican origin and *Z.bicolorata* has evolved over thousands of year to utilise the former as its host. There are no reports of feeding by this insect on sunflower in its native range. Since the beetle was collected from the same area and brought into India and results of host specificity tests carried out in Mexico and Australia (McFadyen and McClay, 1981) are similar to those from India (Jayanth and Nagarkatti, 1987), it is unlikely that there is any chance that the beetle introduced into India can be *Z.conjuncta*.

Extensive field observations carried out during 1992-96 clearly showed that feeding by adults of *Z.bicolorata* was noticed on sunflower leaves only when they started migrating after defoliating the weed, provided there was no rainfall during this period. Even in situations where heavy feeding damage was observed, the insect was not observed to breed on the crop under field conditions. The total area of the crop, where feeding by the beetle was noticed, did not exceed 2 ha during any particular year. It was also noticed that the insect deserted the crop within 1-2 days after a heavy downpour. Laboratory studies were, therefore, initiated to understand the erratic feeding behaviour of *Z.bicolorata* on sunflower, so as to get clues regarding its specificity.

Specificity in insects is controlled by a series of behavioural and physiological reactions to stimuli originating from the host plant. The insects respond to these stimuli through various types of sensory structures that have coevolved in the long association and constant interaction between the insect, the host plant and its habitat (Sankaran, 1990). It was suggested by Frankael (1959) that, since basic nutritional requirements of most insects are similar, food selection and specificity must be determined almost entirely by non-nutritional factors. In some insects, a series of stimulatory, inhibitory and deterrent substances regulate host range via characteristic behaviour patterns. In some, it is largely determined by the presence of one or more secondary plant products, which act as phagostimulants.

Adults of *Z.bicolorata* could be induced to feed on tender leaves of sunflower, within six h, by smearing them with a 50 per cent crude aqueous extract of parthenium. Studies using various chemicals extracted from the leaves of parthenium revealed that the sesqueterpene lactone parthenin, specific to *P. hysterophorus*, was the phagostimulant responsible for inducing feeding by adults of *Z. bicolorata* on treated sunflower leaves. Parthenin is present in all parts of the parthenium plant, including pollen grains. Further investigations resulted in the novel finding that [illegible] parthenium pollen or smearing its extracts, on sunflower leaves also induced feeding response in adults. These studies suggested that accumulation of deposits of parthenium pollen or trichomes on leaves of sunflower plants, growing adjacent to the weed stand, during period of scanty rainfall, may have caused feeding by adults of *Z.bicolorata* (Jayanth *et al.*, 1993).

Host transference involves acquisition by the insect of the ability to survive and reproduce on a new host. But feeding on non host plants may occur for various reasons besides host transference. Although host transference has hot occurred among insects used for biological control of weeds, there have been reports of local and temporary damage to non-host plants. Feeding by *Teleonemia scrupulosa* Stal., introduced for biological control of *Lantana camara,* on *Sesamum indicum* in Uganda and *Cactoblastis cactorum* (Bergroth) introduced for control of *Opuntia* spp. on tomato in Australia are two such examples. But it is heartening to note that these insects did not become pests of the crops mentioned (Jayanth, 1993). In situations where an introduced weed control agent temporarily damages a beneficial plant, it may be desirable to take a closer look at the cost/benefit considerations of the importance of the weed versus possible crop damage. For example, the ecological and economic impact of *P.hysterophorus,* which has spread throughout India, are enormous. Since other methods of control are neither economical nor offer long term solutions to the problems posed by this weed, biological control by host specific natural enemies remains the only viable alternative.

Recently, field releases of *Platphalonidia mystica* (Razowski and Becker) (Lepidoptera: Cochylidae) have been initiated in Queensland, Australia, although larval feeding damage occurred on sunflower and dahlia during host specificity testing (Griffiths and McFadyen, 1993). This step was taken in view of the very great problem that *P. hysterophorus* is causing there and the threat of its continued spread into southern Queensland, New South Wales and Victoria.

Taking the above facts into consideration, the best way of avoiding feeding by *Z.bicolorata* on sunflower would be to prevent growth of parthenium adjacent to sunflower fields in drought prone areas. Such a step would avoid build up of the insect population in the immediate vicinity of the crop and thereby the chances of feeding on sunflower leaves.

FUTURE PROSPECTS

The results of the studies carried out so far indicate that that *Z.bicolorata* has the potential to reduce the density of *P. hysterophorus* and encourage the growth of vegetation formerly suppressed by this weed. However, this insect alone may not be sufficient to bring down the population of the weed to the desired level. Besides *Z. bicolorata* is not likely to be effective in all situations, where parthenium is prevalent. It may, therefore, be desirable to import additional natural enemies such as the leaf mining moth *Bucculatrix parthenica* Bradley (Lepidoptera: Bucculatricidae) and the seed feeding weevil *S.lutulentus*. Similarly, importation of host-specific plant pathogens such as *P.abrupta* var. *partheniicola*, which has recently been introduced into Australia (Tomley, 1990), may also contribute to the successful biological control of this noxious weed throughout India.

REFERENCES

AGASHE,S.N. and ABRAHAM,J.N.(1988). Pollen calender of Bangalore city: Part I.**Indian Journal of Aerobiology 1**: 35-38.

BEST,K.F.(1963) Untitled article. **Soil Horizons 4**: 9-10.

CHAKRAVARTHY,A.K. and BHAT,N.S.(1994). The beetle (*Zygogramma conjuncta* Rogers), an agent for the biological control of weed, *Parthenium hysterophorus*L. in India feeds on sunflower (*Helianthus annuus*L.) **Journal of Oilseeds Research 11**: 122- 125.

CHAKRAVARTHY,A.K., BHAT,N.S. and SRIDHAR,S. (1994). The beetle, *Zygogramma conjuncta*(Rogers), a bioagent for the control of the weed, *Parthenium hysterophorus* L. is oligophagous. **Science and Culture 60**: 61-62.

EVANS,H.C.(1987). Life cycle of *Puccinia abrupta* var. *partheniicola*, a potential biocontrol agent of *Parthenium hysterophorus*. **Transactions of the British Mycological Society 88**: 105-111.

FRANKAEL,G.S.(1959). The raison d'etre secondary plant substances. **Science 129**: 1466-1470

GRIFFITHS,M.W. and McFADYEN,R.E.(1993).Biology and host specificity of *Platphalonidia mystica* (Lep.: Cochylidae) introduced into Queensland to biologically control *Parthenium hysterophorus* (Asteraceae). **Entomophaga 38**:. 131-137.

JAYANTH,K.P.(1987a). Investigations on the host specificity of *Epiblema strenuana* (Walker) (Lepidoptera ; Tortricidae), introduced for biological control trials against *Parthenium hysterophorus* in India. **Journal of Biological Control 1**: 133- 137.

JAYANTH,K.P.(1987b). Introduction and establishment of *Zygogramma bicolorata* on *Parthenium hysterophorus* in Bangalore, India. **Current Science 56**: 310-311

JAYANTH,K.P.(1993).Ecological impact of insects introduced for biological control of weeds - conflicting interests. **Current Science 65**: 901-904.

JAYANTH,K.P. and GANGA VISALAKSHY,P.N.(1994). Dispersal of the parthenium beetle *Zygogramma bicolorata* (Chrysomelidae) in India. **Biocontrol Science and Technology 4**: 363-365.

JAYANTH,K.P. and GANGA VISALAKSHY,P.N.(1996). Succession of vegetation after suppression of parthenium weed by *Zygogramma bicolorata* in Bangalore, India **Biological Agriculture and Horticulture 12**: 303-309.

JAYANTH,K.P., GANGA VISALAKSHY,P.N. MALVIKA CHAUDHARY and GHOSH,S.K.(1996). The Parthenium beetle under attack by an indigenous parasitoid. **Insect Environment** (In Press)

JAYANTH,K.P. and GEETHA BALI(1992) Estimation of number of generations of the Mexican beetle *Zygogramma bicolorata* Pallister by measurement of thermal units. **Journal of Entomological Research 16**: 273-276.

JAYANTH,K.P and GEETHA BALI (1993a). Biological studies on *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae), a potential biocontrol agent of *Parthenium hysterophorus*L. (Asteraceae). **Journal of Biological Control 7**: 93-98.

JAYANTH,K.P. and GEETHA BALI (1993b). Diapause behaviour of *Zygogramma bicolorata* (Coleoptera: Chrysomelidae), a biological control agent for *Parthenium hysterophorus* (Asteraceae) in Bangalore, India. **Bulletin of Entomological Research 83**: 383-388.

JAYANTH,K.P. and GEETHA BALI(1993c). Temperature tolerance of *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) introduced for biological control of *Parthenum hysterophorus* (Asteraceae) in India. **Journal of Entomological Research 17**: 27-34.

JAYANTH,K.P. and GEETHA BALI (1994a). Life table of the parthenium beetle *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae) in Bangalore, India. **Insect Science and Its Application 15**: 19-23.

JAYANTH,K.P. and GEETHA BALI.(1994b). Biological control of *Parthenium hysterophorus* by the beetle *Zygogramma bicolorata* in India. **FAO Plant Protection Bulletin 42**: 207-213.

JAYANTH,K.P. and GEETHA BALI(1995)Effect of soil moisture on pupation and adult emergence of *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae). **Journal of Entomological Research 19**: 183-185.

JAYANTH,K.P. and NAGARKATTI,S.(1987). Investigations on the host specificity and damage potential of *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae) introduced into India for the biological control of *Parthenium hysterophorus*. **Entomon 12**: 141-145.

JAYANTH,K.P., SUKHADA MOHANDAS, ASOKAN,R. and GANGA VISALAKSHY,P.N.(1993). Parthenium pollen induced feeding by *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) on sunflower. **Bulletin of Entomological Research 83**: 595-598.

JOEL,D.M. and LISTON,A.(1986). New adventive weeds in Israel. **Israeli Journal of Botany 35**: 215-223.

JOSHI,S.(1990). Parthenium - its biological control In: **Karnataka State on Environment Report IV**, (SALDANHA,C.J. ed) Center for Taxonomic Studies, St.Joseph's College, Bangalore, pp.61-73.

JOSHI,S.(1991). Interference effects of *Cassia uniflora* Mill. on Parthenium *hysterophorus*L. **Plant and Soil 132**: 213-218.

KRISHNAMURTHY,K. RAMACHANDRA PRASAD,T.V., MUNIYAPPA,T.V. and VENKATA RAO,B.V.(1977) Parthenium, a new pernicious weed in India. **Technical Series No.17**, University of Agricultural Sciences, Bangalore, 46 pp.

KUMAR,A.R.V.(1992) Is the Mexican beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) expanding its host range? **Current Science 63**: 729-730.

KUMAR,S., JAYARAJ,S., and MUTHUKRISHNAN,T.S. (1979) Natural enemies of *Parthenium hysterophorus*Linn. **Journal of Entomological Research 3**: 32-35.

MANI,A.(1985). A study of the climate of Bangalore. In : **Essays on Bangalore** (VYASULU,V. and REDDY,A.K.N. eds). Volume 2. Karnataka State Council for Science and Technology, Bangalore, India.

McCLAY,A.S.(1980). Studies on some potential biocontrol agents for *Parthenium hysterophorus* in Mexico. In: **Proceedings of Fifth International Symposium on Biological Control of Weeds**, Brisbane, Australia, pp. 471-482.

McFADYEN,R.E.(1985). The biological control programme against *Parthenium hysterophorus* in Queensland. In: **Proceedings of the Sixth International Symposium on Biological Control of Weeds** (DELFOSSE,E.S., ed) **Ottawa, Canada**, pp. 789-796.

McFADYEN,R.E. and McCLAY,A.S.(1981). Two new insects for the biological control of parthenium weed in Queensland. **Proceedings of the Sixth Australian Weed Conference 1**: 145-149.

NARASIMHAN,T.R., ANANTH,M., NARAYANA SWAMY,M., RAJENDRA BABU,M., MANGALA,A. and SUBBA RAO,P.V.(1980). Toxicity of *Parthenium hysterophorus*L.: Parthenosis in cattle and buffaloes. **Indian Journal of Animal Science 50**: 173-178.

RAO,R.S.(1956). Parthenium - a new record for India. **Journal of Bombay Natural History Society 54**: 218-220.

RAO,M., PRAKASH,O and SUBBA RAO,P.V.(1985). Reagenic allergy to *Parthenium* pollen: an evaluation by skin test and RAST. **Clinical Allergy 15**: 449-454.

SANKARAN,T.(1990). Biological control of weeds with insects: a dynamic phenomenon of insect-plant interaction. **Proceedings Indian Academy of Science (Animal Science) 99**: 225-232.

SUKHADA,D.K. and JAYACHANDRA (1979). Allelopathic effects of *Parthenium hysterophorus* L.I. Exudation of inhibitants through roots. **Plant and Soil 53**: 27-35.

SUKHADA,D.K. and JAYACHANDRA (1980a). Allelopathic effects of *Parthenium hysterophorus* L. II. Leaching of inhibitants from aerial vegetative parts. **Plant and Soil 55**: 61-66.

SUKHADA,D.K. and JAYACHANDRA (1980b) Pollen allelopathy-a new phenomenon. **New Phytologist 84**: 739-746.

TOMLEY,A.J.(1990).Parthenium rust *Puccinia abrupta var. partheniicola* **Proceedings of the 9th Australian Weeds Conference**, pp.511-512.

TOWERS,G.H.N., MITCHELL,J.C., RODRIGUEZ,E., and BENNETT,F.D.(1977). Biology and chemistry of *Parthenium hysterophorus*L., a problem weed in India. **Journal of Scientific and Industrial Research 12**: 672-684.

VARTAK,V.D.(1968). Weed that threatens crops and grass lands in Maharashtra. **Indian Farming 18**: 23, 43.

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DIURNAL COURSE OF CERTAIN LEAF MOISTURE CHARACTERS IN IRRIGATED AND UNIRRIGATED BLACK GRAM

R. CHANDRA BABU AND P.S. SRINIVASAN

Department of Crop Physiology
Agricultural College and Research Institute
Tamil Nadu Agricultural University
Coimbatore 641 003

ABSTRACT

The effect of irrigation on diurnal changes of certain leaf moisture characteristics was studied during early bean filling in black gram. There was a reduction in leaf water potential and transpiration, while there was an increase in leaf temperature and stomatal resistance as the day advanced from 8 to 14 h. Irrigation had favourable influence on the leaf moisture characters while non- irrigation proved deleterious. Mid-day observations of the leaf moisture parameters are advisable in the screening of black gram cultivars for drought.

KEY WORDS : Leaf Moisture Characters, Black gram, Drought Response