Successful Biological Control of *Chromolaena odorata* (Asteraceae) by the Gall Fly *Cecidochares connexa* (Diptera: Tephritidae) in Papua New Guinea

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Abstract

The impact of the stem-galling fly *Cecidochares connexa* (Macquart) introduced into Papua New Guinea to control *Chromolaena odorata* (L.) King and Robinson was assessed. Field plots were established to determine the impact of the agents on chromolaena and a questionnaire was developed to determine any benefits to landholders. Over 115,000 galls were released in the 13 provinces infested with chromolaena and establishment was readily achieved. Populations increased quickly and the gall fly spread up to 100 km from some release sites. The gall fly caused a decrease in cover, height and density of chromolaena. Chromolaena is now considered under control in nine provinces, resulting in the re-establishment of food gardens and the regeneration of natural vegetation. In socio-economic surveys, over 80% of respondents believed that there is substantially less chromolaena now than before the gall fly was introduced. There has been a significant reduction in the time spent weeding chromolaena and an increase in the size of food gardens, thus increasing productivity and income for landowners. Indirect benefits due to the control of chromolaena include reduced harbor for snakes and wild pigs, reduced need to erect fences around food gardens to exclude pigs, and fewer lacerations resulting from the need to slash chromolaena. It is anticipated that the gall fly will continue to spread and reduce the impact of chromolaena in PNG.

Introduction

Chromolaena odorata (L.) King and Robinson (Asteraceae) (chromolaena) is a woody shrub native to tropical America and the Caribbean. It was first reported in Papua New Guinea (PNG) in East New Britain Province in the 1960s (Henty and Pritchard, 1973), presumably spread from South-East Asia, during or soon after World War II. It subsequently spread to other provinces, through the movement of people and machinery, particularly logging equipment (Day and Bofeng, 2007). Chromolaena affects agricultural production, particularly small subsistence farms and natural ecosystems. It can quickly invade cleared lands and smother crops such as taro, yams, papaw and bananas. Its presence increases the time spent in weeding farms, thus causing some landholders to farm smaller plots (Orapa, 1998; Day and Bofeng, 2007). As a result, yield and income is reduced and clearing new areas for gardening becomes increasingly difficult. In plantations, it can form a complete understory, impeding landholders from collecting coconuts and oil palm nuts. Chromolaena also infests grazing lands, displacing preferred pasture species, and reducing productivity. Regeneration of plant species in logged areas and natural succession is also adversely affected by chromolaena (Orapa et al., 2002).

In 1991, a biocontrol program for chromolaena, funded by the Australian Government and managed by the Queensland Government, was initiated in Indonesia and the Philippines. The moth *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae) and the stem-galling fly *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) were introduced. In 1998, the project was extended to PNG. *P. pseudoinsulata* was introduced into PNG from Guam where it had successfully established (Muniappan et al., 2007) and *C. connexa* was introduced in 2001 from the Philippines, with both agents establishing (Bofeng et al., 2004). The leaf-mining fly *Calycomyza eupatorivora* Spencer (Diptera: Agromyzidae) was introduced unsuccessfully in 2004 from South Africa, where it had established (Day et al., unpubl. data).

C. connexa spread rapidly from all sites and exerted control in many parts of the country. *P. pseudoinsulata*, however, was more limited in its distribution and impact (Day and Bofeng, 2007). Field monitoring was conducted at several sites and a survey was conducted to gauge potential benefits to landholders from the introduction of *C. connexa*. This paper reports on the impact of *C. connexa* on chromolaena in PNG and its subsequent benefits to landholders.

Materials and Methods

Mass-rearing, field release and monitoring

C. connexa was initially mass-reared in cages (90 cm x 56 cm x 88 cm) by placing 5-10 pairs of adults into cages containing pots (250 mm dia) of large chromolaena plants. Cages were sprayed with water to allow the flies to drink. Plants were removed after three days and held for gall development. New plants were then added to the same cage and the process was repeated until the adults had died after about 11 days (Orapa and Bofeng, 2004).

Stems with mature galls were cut and released in the field, in batches in plastic cups filled with water, placed under clumps of chromolaena. Early in the release program releases of 500 galls were conducted but the number per release was reduced subsequently to 100, with little change in establishment success.

Once *C. connexa* had established in the field and populations increased sufficiently, it was more efficient to collect galls from the field. Over 2,000 galls could be collected in a few hours compared to a few weeks if being mass-reared. Release sites were checked after three months following releases, by which time galls should be present in the field.
Intensive field monitoring was conducted at five sites in Morobe Province where the project was based and one site in East New Britain Province. A 100 m transect line was run through each study site and the percent chromolaena covering the line was calculated. At each site, five fixed 1 m2 quadrats were established and the number of stems and their height recorded. The number of galls per stem was also recorded. Monitoring was conducted approximately every two months until there were no plants remaining in the quadrats.

Socio-economic assessment

To gauge the impact of the project and specifically the introduction of the gall fly on landholders, a survey form of 22 questions was developed. The form gathered information on province and land use of each respondent and estimated the impacts of the gall fly in terms of changes in abundance of chromolaena post release of the gall fly, as well as changes in time spent weeding, cost of control, yield and income. The final question attempted to gain an overall view of the project and the introduction of the gall fly.

Surveys were conducted only in provinces where the gall fly had established and respondents were chosen randomly at roadside markets to minimize bias towards particular land uses or weed control status.

Results

Mass-rearing, field release and monitoring

Over 115,000 galls were released at over 350 sites in all 13 provinces infested with chromolaena. The establishment rate was 99% and the few sites where the gall fly failed to establish were sites that were slashed or burned soon after releases. There are still 22 sites where establishment is yet to be confirmed. The gall fly spread rapidly, up to 100 km in seven years from some sites. Spread was assisted by landholders who readily moved the gall fly around. By mid 2011, the gall fly was present at 89% of all known sites with chromolaena, covering 12 provinces, with the only chromolaena site in Western Province still to be checked. There are still about 50 sites, mainly in remote areas, where the gall fly has not yet been released or is not present (Fig.1).

Chromolaena is considered under control at over 200 sites in nine provinces, namely Bougainville, East New Britain, Eastern Highlands, Madang, Manus, Morobe, New Ireland, Oro and Sandaun. Stem or branch dieback was noticeable where the number of galls per plant exceeded 20.

At the six monitoring sites, chromolaena cover, height and density decreased with the presence of the gall fly. Complete control of chromolaena, where plants disappeared from all quadrats and about 80% of transect lines occurred at three sites, namely Kasuka (Fig. 2), Trukai Farm (Fig. 3) and Wantoat Road (data not shown), all in Morobe Province. At the remaining study sites, fires and slashing also contributed to the control of chromolaena.

Socio-economic assessment

Over 190 interviews with landholders from over 100 villages in eight provinces were conducted. A large proportion of respondents (44%) were from East New Britain, and most (67%) were mixed cropping subsistence farmers. Approximately 83% of all respondents reported less chromolaena after the gall fly was released, irrespective of province and land use. However, in East Sepik Province, where releases were made later and the full effect of the agent may not yet have been achieved, only 60% of respondents thought there was less chromolaena now than before the gall fly was introduced.

Over 50% of respondents stated that there was about half the chromolaena present following the introduction of the gall fly. Interestingly, about 12% thought that chromolaena was still increasing. Most of these people were in areas where the gall fly had been released more recently and may not yet had time to have much impact on chromolaena (Fig. 4).

There was an overall decrease in the time spent controlling chromolaena. About 33% of respondents stated that they spend less than half the time controlling the weed than before the gall fly was released, including over 7% who no longer use any control methods (Fig. 5). Similar trends were observed for the cost of controlling chromolaena after the release of the gall fly, with 26% of respondents reporting that control costs had been reduced by 50% since the introduction of the gall fly (Fig. 6).

There was a subsequent increase in yield and income after the introduction of the gall fly, with about 60% of respondents reporting an increase in yield and income (Fig. 7 and 8). About 36% of the landholders reported moderate to substantial benefits of the project and thought the introduction of the gall fly was most useful. About 31% of respondents reported minor benefits from the project (Fig. 9).

In addition, there were many anecdotal benefits reported; from a decrease in knife wounds resulting from the reduction in the need to slash chromolaena to fewer snakes or wild pigs hiding in chromolaena infestations. Villagers also reported that roadsides did not have to be slashed so often to maintain adequate visibility and access.

Discussion

C. connexa is the most successful of the three biocontrol agents introduced into PNG to control chromolaena. Not only was it easy to mass-rear, field-release and establish, it spread quickly from the point of release, moving up to 100 km in seven years. *C. connexa* is now present at 89% of known chromolaena sites throughout PNG and is expected to keep dispersing as chromolaena also spreads. However, it is also expected that the fly will reduce the rate of weed spread.

Complete control of chromolaena was observed at three of the monitoring sites, while at the other sites, there has been a general decrease in the size of chromolaena infestations. While formal monitoring was not undertaken in other provinces, similar trends were observed.

In most provinces, chromolaena is considered under control by the gall fly in at least some areas. Control was generally achieved more quickly in some provinces, particularly East New Britain, New Ireland and Bougainville, than in others such as Morobe and Madang where it is drier (Day and Bofeng, 2007). Control in West New Britain has been slower and less complete, possibly due to the cloudy conditions affecting mating and oviposition of *C. connexa* (R. McFadyen pers. comm., 2010; Day et al., unpubl. data).

The introduction of the gall fly into PNG has been well received, with landholders stating that there is significantly less chromolaena present now than before the gall fly was introduced. Consequently, there is a substantial decrease in weeding times and costs to control chromolaena. In addition, there has been a substantial increase in yield and income and part of this has been due to an increase in the size of farmed lands, due to the reduced effort to weed and manage the land.

Thus controlling chromolaena in PNG has increased food security and income of landholders, as well as increasing general health and well-being through decreased knife wounds and snake bites. The decrease in weeding times has also allowed landholders the opportunity to undertake other activities, such as maintenance of houses, fences and fishing nets.

C. connexa has also been released in Indonesia, Guam, Federated States of Micronesia and Palau where it controls chromolaena (Muniappan et al., 2007; Zachariades et al., 2009). More recently, *C. connexa* was re-introduced into Thailand and is being considered for introduction into Australia, China and Taiwan.

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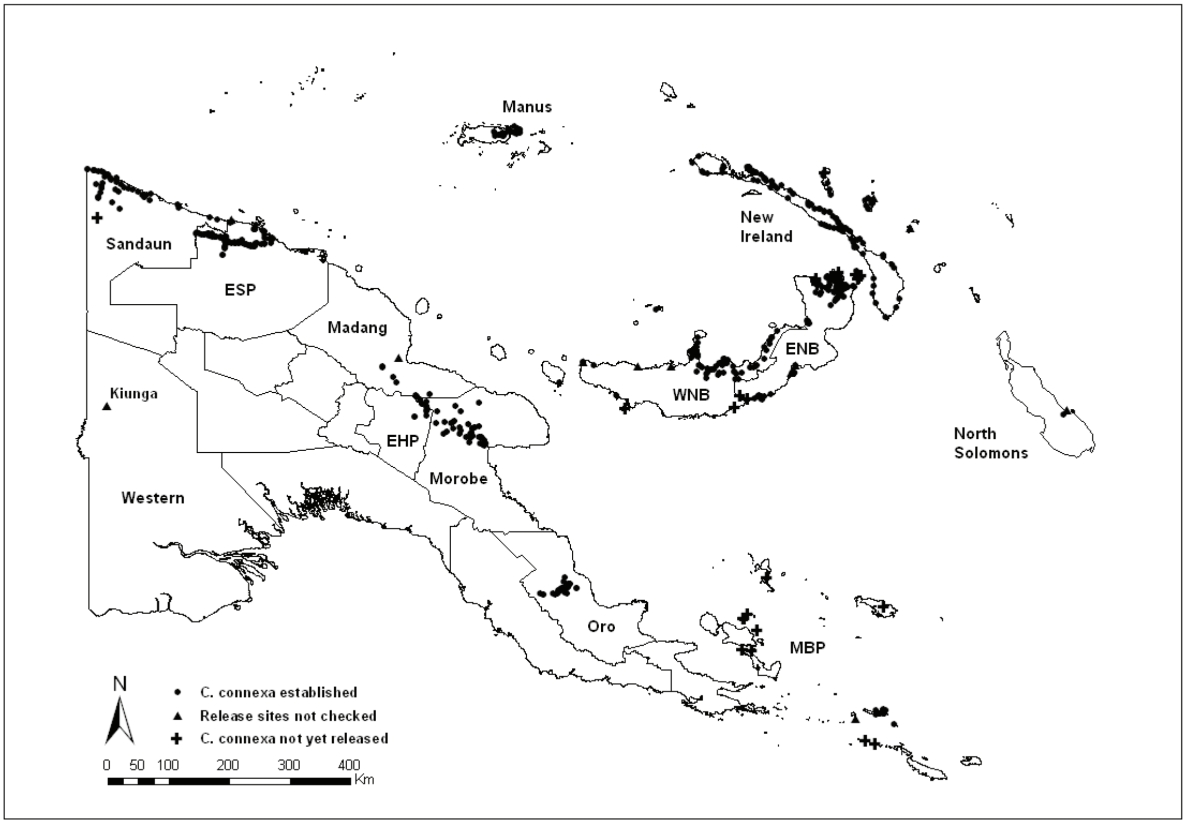

Figure 1. The distribution of *C. odorata* in Papua New Guinea (all dots), showing where *C. connexa* has established, been released but not checked and where it is yet to be released. EHP = Eastern Highlands Province; ENB = East New Britain; ESP = East Sepik Province; MBP = Milne Bay Province; WNB = West New Britain.

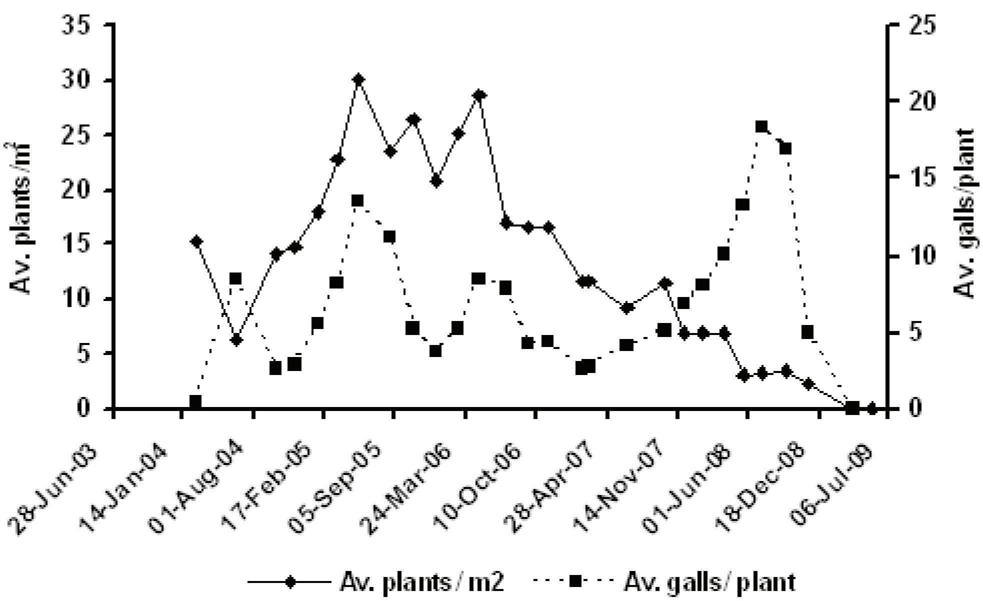

Figure 2. Mean number of plants/m^2 and the mean number of galls/plant over time at Kasuka, Morobe Province.

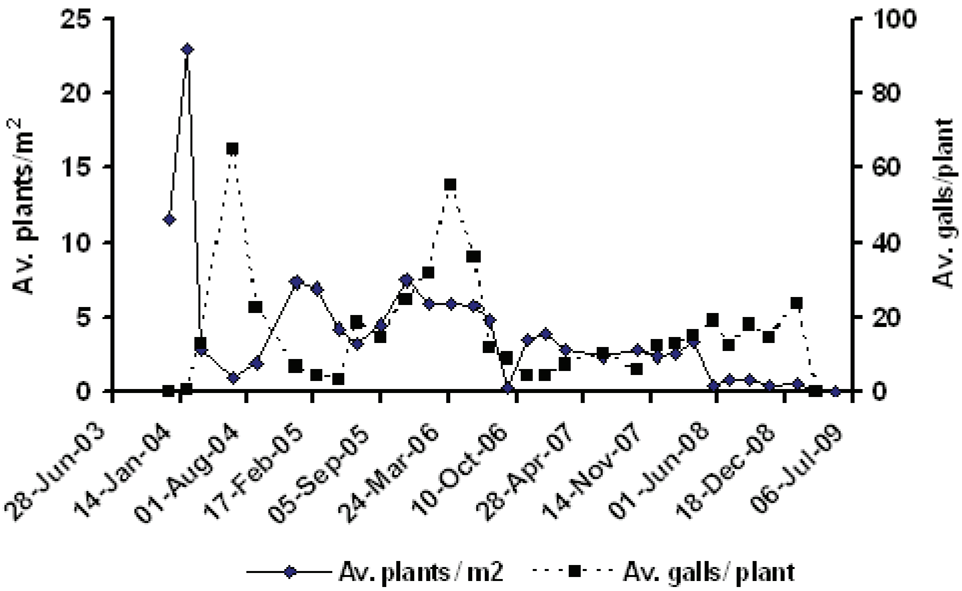

Figure 3. Mean number of plants/m^2 and the mean number of galls/plant over time at Trukai Farm, Morobe Province.

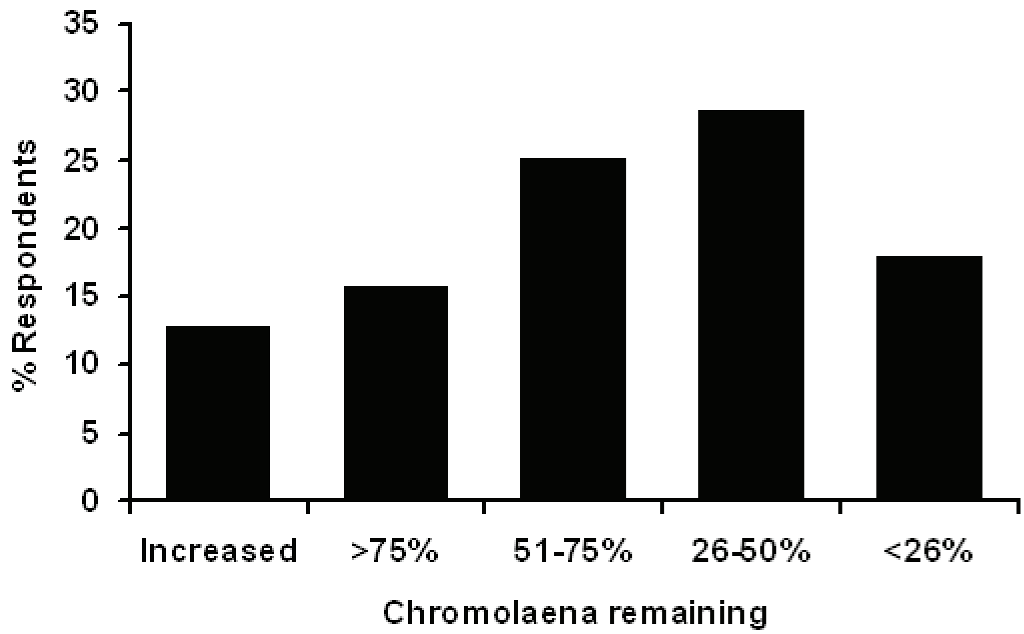

Figure 4. Responses when landholders were asked how much chromolaena remained after the gall fly was introduced.

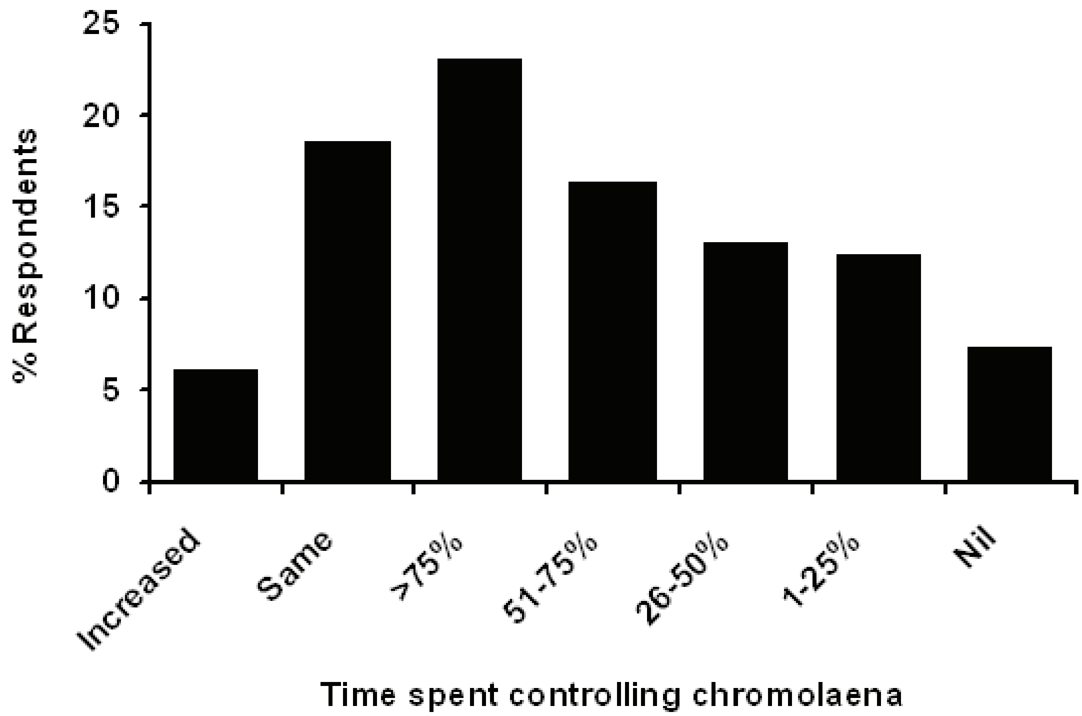

Figure 5. Responses when landholders were asked how much time is now spent on controlling *Chromolaena* compared to before the gall fly was introduced.

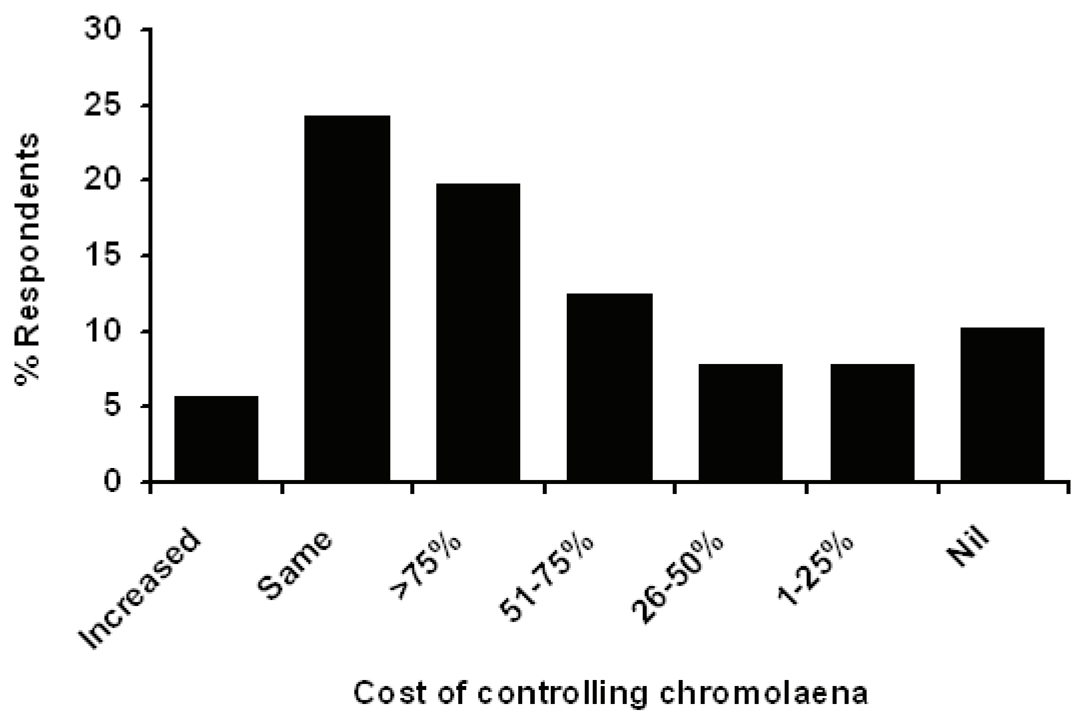

Figure 6. Responses when landholders were asked how much the cost of controlling *Chromolaena* has changed compared to before the gall fly was introduced.

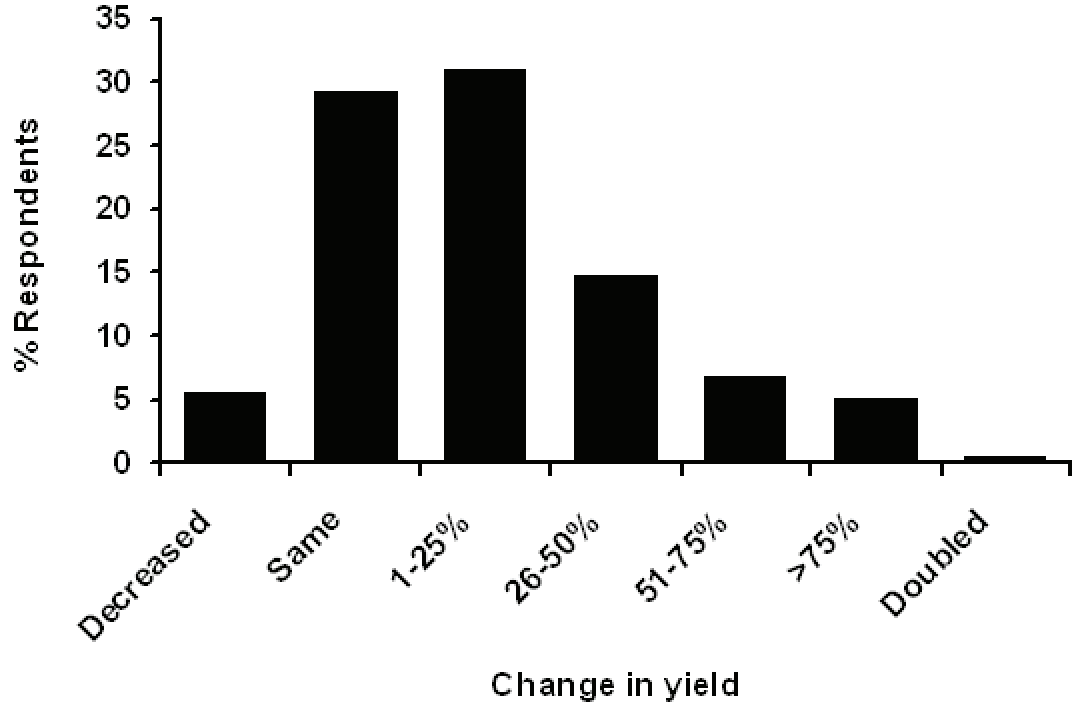

Figure 7. Responses when landholders were asked how much yield has increased compared to before the gall fly was introduced.

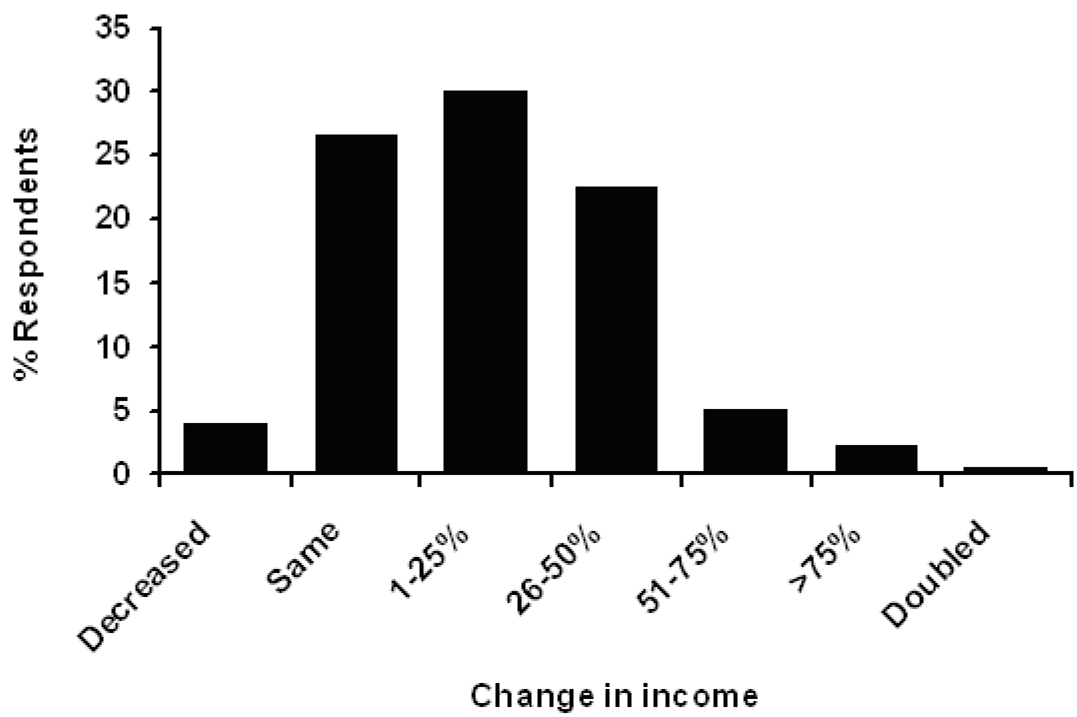

Figure 8. Responses when landholders were asked how much income has increased compared to before the gall fly was introduced.

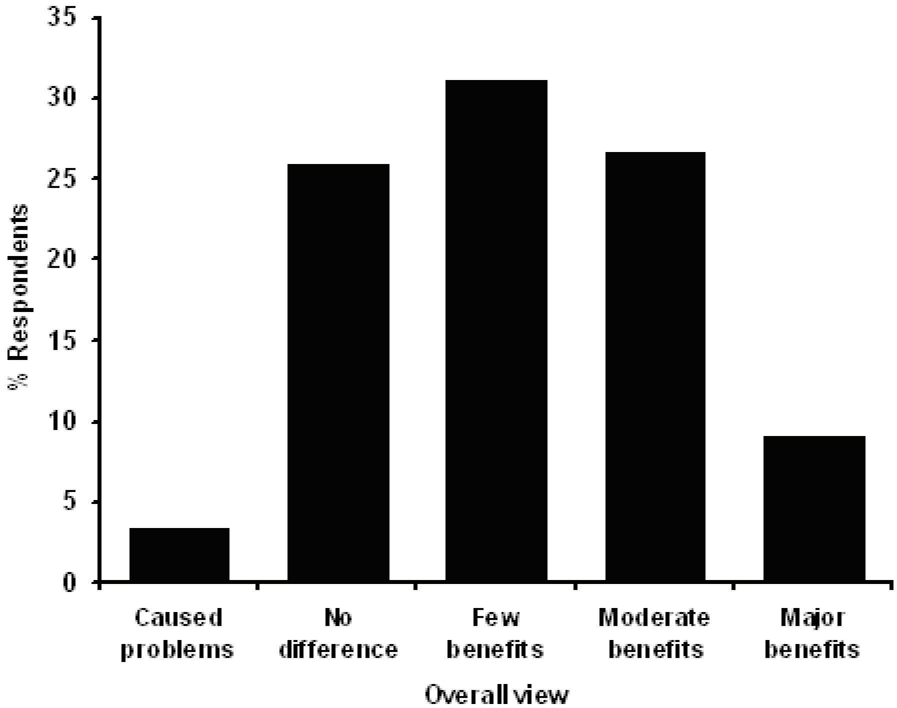

Figure 9. Responses when landholders were asked their overall view of the biocontrol project and the introduction of the gall fly.