Darwin Initiative Main: Annual Report

Project reference	**29-012**
Project title	Protecting biodiversity through biocontrol of papaya mealybug in East Africa
Country/ies	Kenya, South Sudan, Uganda
Lead Partner	CABI
Project partner(s)	Kenya Plant Health Inspectorate Service (KEPHIS), Kenya Agricultural and Livestock Research Organization (KALRO), National Museums of Kenya (NMK), National Agricultural Research Organization (NARO), University of Juba (UoJ)
Darwin Initiative grant value	**£501,479.00**
Start/end dates of project	1.June. 2022 – 31. March. 2025
Reporting period (e.g. Apr 2023 – Mar 2024) and number (e.g. Annual Report 1, 2, 3)	1. April 2023 – 31. March 2024; Annual Report 2
Project Leader name	Ivan Rwomushana
Project website/blog/social media	https://www.cabi.org/projects/biocontrol-of-papaya-mealybug-in-east-africa/
Report author(s) and date	Ivan Rwomushana; 30. April. 2024

1. Project summary

The project aims to address biodiversity challenges related to the invasion of papaya mealybug (PMB) in East Africa (EA). PMB is an invasive pest native to the Americas that spread rapidly in East Africa between 2015- 2022, causing significant yield loss of up to 57% and household economic losses estimated at £2,224/ha annually. Management of PMB by farmers in EA has largely relied on the use of highly hazardous pesticides. Excessive use of pesticides is the second most important driver for the worldwide decline in insect populations, negatively impacting insect biodiversity by eliminating native pollinators and natural enemies of pests. Resource-limited smallholder farmers, especially women, are most affected by biodiversity loss as they are most directly dependent on insect pollinators for their crop production.

Since 2022, with funding from the Darwin Initiative, CABI and partners have combined efforts to manage this pest through the use of the encyrtid wasp (*Acerophagus papayae*) - a biological control agent – as part of an Integrated Pest Management strategy for the papaya mealybug in Kenya, aiming to also conserve native insect biodiversity through reducing pesticide use, the hitherto go-to control method. Classical biological control (CBC) of PMB has been identified as a sustainable control measure through stakeholder activities under a Darwin-funded project. Following efficacy tests and high laboratory parasitism in quarantine, the Kenyan, Uganda and South Sudan regulators granted permission for the field release of *A. papayae* against PMB. The release of the parasitoid will reduce the heavy reliance on pesticides and protect native insect diversity, ensuring a healthier ecosystem.

The project is relevant for farmers, consumers, and the environment. The release of the parasitoid for PMB management will result in higher yields, reduced economic losses, and a

healthier ecosystem. Resource-limited smallholder farmers, especially women wo are the main papaya growers in these countries, will benefit the most from the project. With access to sustainable control methods, they can safeguard their crop production without being adversely affected by the decline in insect biodiversity resulting from excessive pesticide use.

Moreover, the project aims to address poverty and human development challenges by reducing economic losses and ensuring food security. The decline in crop yields due to PMB invasion has led to substantial economic losses for smallholder farmers. Parasitoid release will mitigate these losses, leading to higher income and improved livelihoods. Additionally, the project will bolster food security by maintaining crop yields and reducing reliance on costly and hazardous pesticides.

These challenges were identified through scientific studies and stakeholder consultations in the implementing countries. Predictions indicate that without sustainable management, PMB will continue to spread rapidly across new areas in East Africa. Recent studies in Kenya and Uganda show positive farmer attitudes towards biological control agents, highlighting the need for sustainable control measures. The activities of this project are undertaken in PMB-infested farms in Kenya, Uganda and South Sudan (Fig.1)

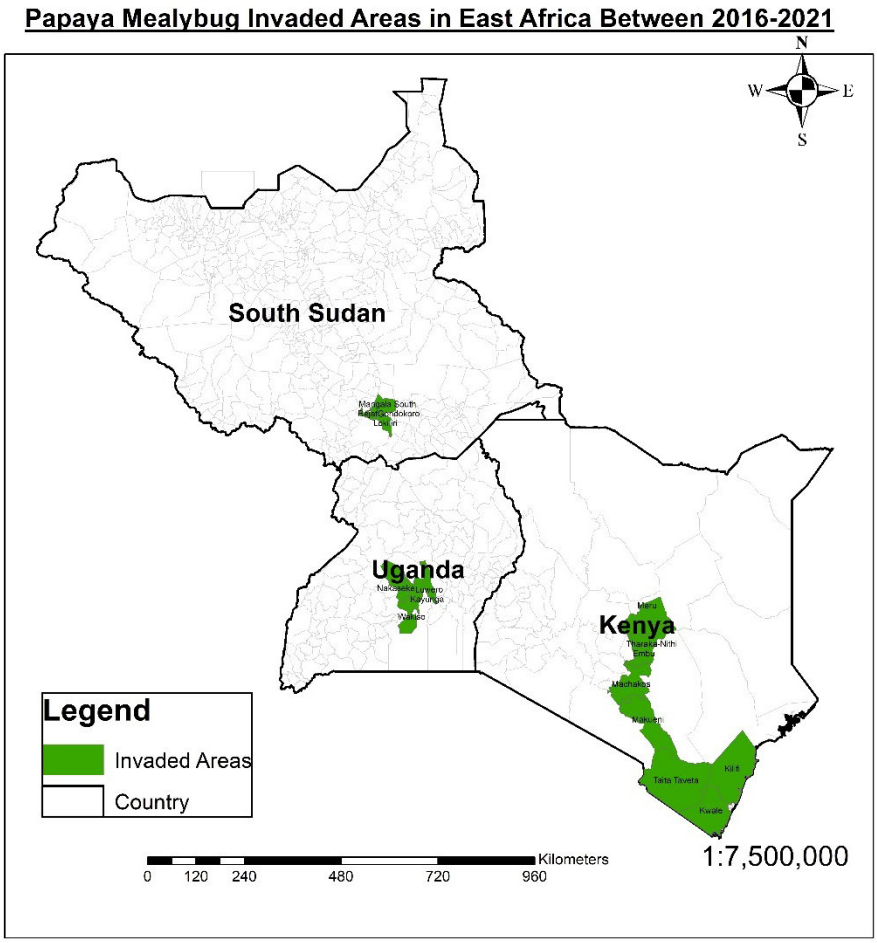

Figure 1: Papaya invaded areas in Kenya, Uganda, and South Sudan

2. Project stakeholders/ partners

Partnerships were established with one National Plant Protection Organisation (KEPHIS), three research organisations (NARO, KALRO, and NMK), and one university (UoJ) in response to in-country demand and initial consultations aimed at PMB management in East Africa. The project has been highly participatory, and all partners have actively participated in the inception meeting, project planning and review meetings, decision-making, and report production (Annex 4.1, 4.2 and 4.3: Inception Report and Planning Review and Planning Meeting Reports). Regular

meetings, conducted via Zoom or phone, are held among partners to review progress and address any emerging issues. Sub-grant agreement contracts were signed by all partner institutions except NMK where CABI spends directly on behalf of the partner due to institutional bureaucracies (see Table 1), with the first disbursements made after a successful inception meeting in 2022 and subsequently phased after submission of verifiable expense accountabilities.

Since then, robust collaboration and activities have been observed among all partners. Joint training and field activities have been conducted by implementing partners in various countries to maximize resources and achieve more within a short period. For example, CABI and NARO conducted a Participatory Rapid Rural Appraisal in Uganda to assess farmers' knowledge and practices regarding PMB biocontrol, with findings jointly shared through a feedback workshop. Training sessions on PMB biocontrol and parasitoid conservation were held in Kenya, involving CABI, KALRO, KEPHIS, UoJ and NMK, with >200 extension officers trained. Biodiversity assessments were carried out in biological learning sites in Kenya, South Sudan, and Uganda.

Joint efforts were also made in the three countries to apply for import or release permits (Annex 4.4, 4.5), site selection, conduct training of extension officers, farmers and crop inspectors and awareness (Annex 4.6a, 4.6b, 4.7, 4.8, 4.9a, 4.9b, 4.9c), and produce technical materials facilitating training and other activities. Notable technical outputs include the PMB Integrated Pest Management training manual (Annex 4.10), PMB technical brief (Annex 4.11), and a communication and gender strategy (Annex 4.12). Additionally, blogs have been jointly published on various activities under the project (See links to blogs in this report).

Table 1: Sub-grant agreement status by the DI partners.

Institution	Y1	Y2- Addenda	Y3- Addenda
KALRO	Signed	Signed	Submitted
KEPHIS	Signed	Signed	Submitted
NARO	CABI spending directly	Signed sub-grant agreement	Submitted (1st addendum)
UoJ	Signed	Signed	Submitted
NMK	Not signed- CABI spending directly	Not signed- CABI spending directly	Not signed- CABI spending directly

3. Project progress

3.1 Progress in carrying out project Activities

Output 1: The *A. papayae* parasitoid released and naturalized in East Africa for the sustainable biological control of papaya mealybug and protection of native insect biodiversity.

Activity 1.1: Conduct ecological niche modelling to evaluate the environmental suitability for A. papayae across East Africa to identify potential release areas.

Ecological niche modelling was performed for *A. papayae* in Kenya to evaluate the suitability of environmental conditions for its establishment in the country in the previous reporting period. Subsequently, this analysis was extended to encompass other African countries (including project countries- Uganda and South Sudan) in relation to areas invaded and/or with the potential to be invaded by PMB. The results revealed high suitability for *A. papayae* to establish in all project-implementing countries, providing crucial insights for the release of this parasitoid beyond Kenyan farms. This work has been slated for submission to the Journal of Biological Control in Y3 (see figure 2) and draft of manuscript for submission for peer review (Annex 4.13).

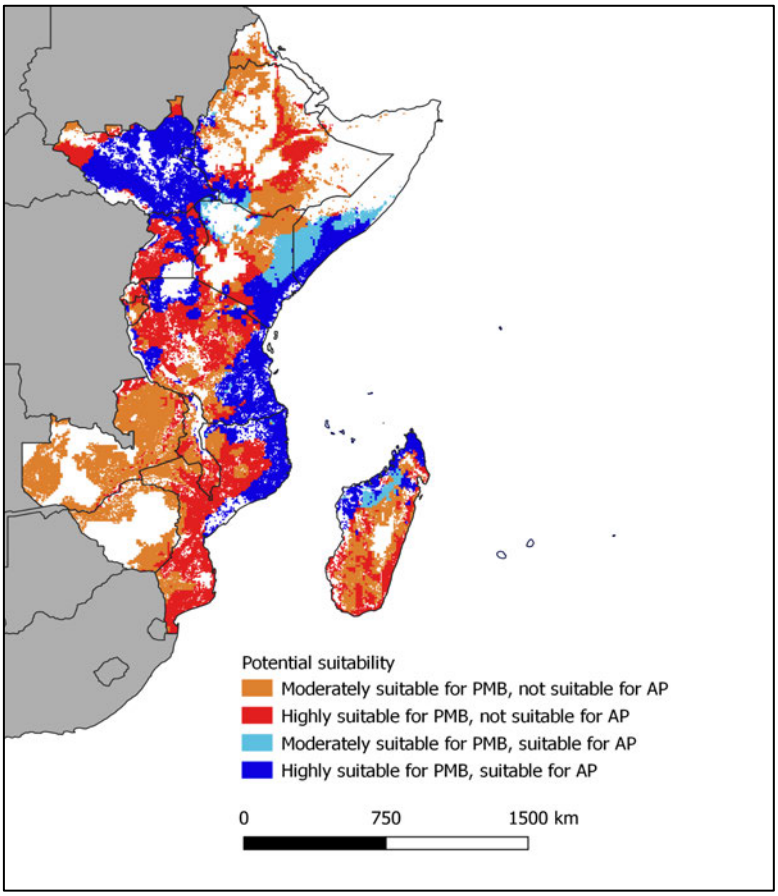

Figure 2: Modelled climate suitability *Paracoccus marginatus* and *Acerophagus papayae* across cropping areas of Eastern Africa.

Activity 1.2: *Undertake a baseline study at selected biological control learning sites to determine the native insect biodiversity under farmers' practices.*

Biodiversity assessments have been carried out in all three implementing countries at selected biological learning sites. The main objectives of these studies were to assess the native insect and plant diversity in papaya farms that will be designated as learning sites for PMB biocontrol before the introduction of the parasitoid. The studies covered 13 farms in Kenya, 3 in South Sudan and 6 in Uganda. Standard insect and plant sampling protocols were used to collect data on biodiversity in these sites. Plant and insect checklists (and reports) have been developed from these studies. The insect reports (and checklists) highlight the functional groups and ecological roles of the sampled insects, categorizing them as pests, pollinators, predators, decomposers, scavengers, attendant ants, parasitoids, vectors of pathogens, and food sources. Notably, a significant number of natural enemies, particularly parasitoids (8%) and predators (22%), were identified in the samples from Kenya, Sudan and Uganda where pesticides are not routinely used (See Annex 4.14a, 4.14b, 4.15a, 4.15b, 4.16a, 4.16b, 4.16c). These findings suggest the potential for further conservation of these natural enemies in biocontrol efforts against PMB and other economically significant pests. Additionally, beneficial insects such as pollinators and decomposers were also identified in the study. A post-intervention (parasitoid release) study will be carried out to assess the change in abundance of the insect diversity in Y3 in areas where pesticide use has reduced with the introduction of the biological control agent. At a few sites, one notable observation when pesticide use was stopped with the introduction of *A. papayae*, there is a reported increase in the number of scale insects (coconut scale). This seems to suggest that there must be a good balance between conserving other native insects and the resurgence of damaging pest species.

Activity 1.3: *Conduct area-wide releases of A. papayae in Kenya, South Sudan and Uganda using hand releases and deploying technology such as drones and landscape scale, Y3 Q3*

In the second year, following the completion of the protocol for mass releases of the parasitoid (Annex 4.17), several mass releases (including augmentation) of the parasitoid have been undertaken in three coastal counties of Kilifi, Mombasa and Kwale in Kenya and the central district in Uganda (Annex 4.18, 4.19). These efforts have reached over papaya 250 farms with over a million parasitoids released. Additionally, preliminary post-release assessments in the release sites have been conducted in the three aforementioned areas confirming both successful establishment and dispersal of the parasitoid (Annex 4.20, 4.21). While these assessments have predominantly concentrated on the primary release sites and a selection of non-released farms situated near the treated ones, more comprehensive evaluations are planned in Y3 to further confirm the extent of dispersal. The complete findings from these assessments will be presented in the forthcoming annual report. At the farm level, the establishment of parasitoids has been facilitated by the construction of Natural Enemy Field Reservoirs (NEFRs). Within the reporting period, the project has successfully erected a total of 22 NEFR prototypes across the three Kenyan counties, alongside several others managed by local farmers. Additionally, augmentation activities in three sites have been carried out to support the establishment of the parasitoid. In light of these accomplishments, an extension of the release permit (Annex 4.22a, 4.22b) has been authorized by the Kenya Standing Technical Committee on Imports and Exports (KSTCIE) for an additional five counties, in addition to the original three coastal counties.

In Uganda, efforts to introduce the parasitoid received a significant boost with the authorization from the National Task Force (NTF) for quarantine rearing and field release. This decision followed a comprehensive application, review, and presentation to the committee. In addition to granting permission for the introduction of the parasitoid into quarantine, the committee recommended further research to assess the impact of the Papaya Mealybug (PMB) on other economically important host species within the country, apart from papaya (Annex 4.24a, 4.24b). Subsequent to this approval, critical steps were taken to realize this initiative. The quarantine facility at NARO, Kawanda, was refurbished, and a starter colony of 1,000 parasitoids was imported from CABI's biocontrol laboratories in Kenya. These parasitoids were reared for two generations before field release. Furthermore, three technical staff members from NARO were trained at CABI Kenya in PMB biocontrol and quarantine procedures, and they will play a pivotal role in managing the quarantine facility and maintaining the parasitoids (Annex 4.24). Since its introduction, field releases have been conducted in three districts in Uganda (Mukono, Kayunga, Luwero) (Annex 4.25).

In South Sudan, extensive field surveys were carried out to identify additional release and learning sites within Central, Western, and Eastern Equatoria states. The primary objective was to pinpoint farms suitable for biodiversity assessments and the initial release of parasitoids. This led to the identification of three categories of farms: purely organic farms, intensively sprayed farms, and farms located on islands, offering valuable opportunities for counterfactual studies. Additionally, biodiversity assessments were performed at the identified learning sites. While an import permit was acquired for the introduction of the parasitoids in South Sudan, no releases have been made yet in the country. This is due to among other challenges, the limited organised papaya farming (more of kitchen gardens) with only a few farms (those identified in the biodiversity studies) fitting the bill. However, plans are underway in Y3 to release in these farms in addition to targeting other economically important crop hosts in South Sudan (cassava, okra, hibiscus) that are equally affected by PMB.

Activity 1.4: Establish A. papayae reservoirs on farmers' fields for parasitoid mass production in situ for augmentative field releases during naturalization, Y1 Q3; Y2 Q2 and Y3 Q3

Training on the in-situ parasitoid production on the establishment of the Natural Enemy Field Reservoirs (NEFRs) has been conducted for farmers in Kenya and selected farmers in Uganda. NEFR prototypes have been developed and piloted in Kenya and Uganda (Annex 4.26). In the reporting period over 22 NEFRs have been constructed in Kenya and Uganda, alongside several other farmer-managed ones to support the establishment of *A. papayae* in the farmers' field (Annex 4.27, 4.28). This activity will be replicated in South Sudan once the parasitoid is introduced. Work on NEFRs and their role in PMB management has also been submitted for

publication in the journal Biocontrol (BCON-D-24-00061) (Annex 4.29). This study showed an increase in parasitism rates (of up to 117%) and PMB population reduction of up to 62.8% in studied farms. Additionally, as a result of deploying NEFRs, the natural (including predators) abundance and diversity increased within these farms. Farmer testimonials in the practising farms have also attested to the importance of NEFRs in facilitating the establishment of *A. papayae* within the farms reducing the need for new introductions for/or during augmentation.

Activity 1.5: Conduct monitoring to determine post-release establishment and parasitoid efficacy as well as expansion outside the release areas, Y1 Q3; Y2 Q2; Y3 Q1, Y4 Q4

Initial assessments and regular farm visits conducted in the release sites in Kenya and Uganda have consistently confirmed the successful establishment and dispersal of the parasitoid (Annex 4.30). Evidence of parasitized PMB (mummies) and flying adults has been observed in fields treated with the parasitoid. While these assessments have primarily focused on the primary release sites and selected nearby farms (especially in Kenya), more comprehensive evaluations are planned in Year 3 to confirm the extent of dispersal. Notably, in Uganda, the parasitoid's spread has been confirmed over more than 20 kilometres from the release sites, demonstrating its rapid establishment and expansion (Annex 4.31). In Kenya, the establishment of parasitoids within farms has been facilitated by the construction of Natural Enemy Field Reservoirs (NEFRs), in addition to augmentation efforts within the release sites. Detailed findings from these assessments will be presented in the forthcoming annual report. Regarding parasitoid efficacy, post-release studies (including with NEFRs) and feedback from farmers have indicated a reduction in PMB infestation in the release sites in both Kenya and Uganda.

Output 2: Capacity of crop inspectors, small-holder farmers, extension providers and the general public enhanced on in situ management of A. papayae on sustainable management of papaya mealybug and biodiversity conservation

Activity 2.1: Train crop inspectors in the identification of papaya mealybug and related scale insects, the A. papayae parasitoid and the biological control-biodiversity conservation nexus, Y1 Q2; Y2 Q1; Y3 Q4

Collaboratively, CABI, KALRO, KEPHIS, and NMK conducted training sessions in Kenya aimed at equipping inspectors with the necessary skills for PMB and other scale insects' PMB identification and damage symptoms, and management with a strong emphasis on biocontrol, NEFRs and in-situ production and conservation (Refer to training materials). Additionally, trainees were taken through the factors contributing to PMB spread, identification of similar scale insects, PMB natural enemies including predators and parasitoids, laboratory rearing techniques for PMB and its parasitoid, PMB management, and parasitoid conservation in the field. A total of 29 inspectors (10 females) have been trained in Kenya. In South Sudan, 10 crop inspectors (2 females) from the Central Equatoria State were trained in PMB biocontrol in collaboration with UoJ. Training of crop inspectors in Uganda is scheduled for Quarter 1 of Year 3.

2.2: Train extension workers and community facilitators on conservation of A. papayae in the field, to support the process of naturalization, Y1 Q3; Y2 Q2, Y3 Q1, Y4 Q3

During the reporting period agricultural extension officers in KE, SS and UG, have been trained on various aspects of PMB biocontrol. During the reporting period, 122 (47 females), 33 (11 females) and 30 (5 females) extension workers have been trained in Kenya, Uganda and South Sudan respectively. To date, the project has trained 319 extension officers (102 female). With scale-out in Y3 on course, more staff are planned to be trained in the three countries. Its important to note that these trained cohort of extension has been instrumental in mass campaigns, alerts, release and post-release activities in Uganda and Kenya. For instance, trained staff in Kenya have facilitated the release and augmentation efforts of the parasitoid beyond the initial release sites. They have also supported the establishment of NEFRs in farmers' fields in addition to reporting the pest population dynamics in relation to weather, information that has been critical in conducting correlations. In Uganda, extension staff have supported in establishing the spread of the parasitoid beyond the primary sites. Additionally, they have supported mass campaigns about the pest and the biocontrol solution. A comprehensive extension training manual for the Integrated Management of Papaya Mealybug (refer to Training Manual), along with a Papaya

Technical Brief, Papaya Pest Management Decision Guide (PMDG), Papaya Photosheet (Annex 4.32), and Papaya Diseases Disorders Pocket Guide were developed, reviewed, and printed. These resources are intended for use by extension officers to enhance their capacity and aid in their work effectively. Following approval by the National Task Force (NTF) for the importation and release of the parasitoids in Uganda, three technical staff were trained (through technical benchmarking at the CABI biocontrol labs) to facilitate the quarantine mass rearing of *Acerophagus papayae.* and future field releases.

2.3: Train farmers on in situ production of A. papayae in their farms, Y3 Q3

During the reporting period, farmers from the three participating counties in Kenya (Kwale, Mombasa and Kilifi) were trained on the in-situ production of *A. papayae.* Additionally following the granting of permission to mass release the parasitoid in 5 extra counties, a mass campaign for site selection was undertaken. Over 300 farmers were reached in Kenya (Annex 4.33). The training included the establishment of the NEFR approach, its monitoring and maintenance. Other topics included PMB identification, its natural enemies and look-alikes, and management. To date, 296 farmers have been trained in Kenya. In Uganda, while separate training for farmers hasn't been undertaken yet, framers selected for field release have been trained. Extended training activities are planned for Uganda and South Sudan in Y3.

Output 3: Scientific evidence-base generated on impacts of classical biological control of *A. papayae* on livelihoods and native insect biodiversity

Activity 3.1: Undertake surveys to establish the effect of pesticide use on native insect biodiversity, comparing fields with and without the parasitoid, and fields with farmers pesticide practices, Y1 Q1; Y1 Q3; Y2 Q1; Y2 Q3; Y3 Q1; Y3 Q3

A post-release study was undertaken in the three coastal counties to assess the effect of pesticide use on native insect biodiversity. Incorporating NEFRs in the studies, the results showed increased natural enemies' abundance and diversity in the farmers' fields in addition to increased parasitism in the parasitoid-treated sites (Annex 4.29, 4.30).

Activity 3.2: Conduct socio-economic studies to determine the impacts of the CBC approach on the population of papaya mealybug and crop infestation, Y3 Q3

This activity has not begun but planned for Y3. However preliminary post-release observations and farmer feedback confirms a reduction in the PMB population in treated fields. A data collection tool is under development to be used for socio-economic studies.

Activity 3.3: Undertake surveys to assess the impacts of A. papayae biological control on yield and incomes of smallholder households, Y3 Q3

This activity has not begun. However, farmers are reporting to returning to papaya farming after initial periods of crop abandonment due to PMB.

Activity 3.4: Generate an inventory of native insect biodiversity pre-and post-release of A. papayae to determine the positive impacts of the classical biological control programme on insect biodiversity; Y1 Q1; Y1 Q4; Y2 Q3; Y3 Q2

Baseline biodiversity assessments have been conducted in all the implementing countries (Ref to Activity 1.2). An inventory of native insect and plant diversity has been developed for all countries (Annex 4.14, 4.15 and 4.16).

Activity 3.5: Conduct surveys to establish impacts of the classical biological control agent on non-target scale insects, Y3 Q3

This activity has not begun but is planned for Y3. A data collection tool is under development to capture this data.

Output 4. Information on classical biocontrol of papaya mealybug and conservation biocontrol approaches to support natural pest regulation and better management of biodiversity packaged and disseminated to increase farmer knowledge and technology adoption

4.1: Develop an effective, gender responsive communication plan, integrating multi-channel communication approaches appropriate for reaching men and women smallholder farmers, Y1 Q3
A gender and communication strategy has been jointly developed by DI partners through a consultative and participatory process (Annex 4.12)

4.2: Produce and disseminate different information products on targeting different stakeholders on dual purpose - pest control and biodiversity conservation nexus, Y4 Q4
During the reporting period, several communication products have been developed.

a. A dedicated project webpage was developed: https://www.cabi.org/projects/biocontrol-of-papaya-mealybug-in-east-africa/.
b. Training manual for extension officers (Annex 4.10)
c. A papaya mealybug technical brief (Annex 4.11)
d. Papaya mealybug photosheet (Annex 4.32)
e. An awareness video on PMB management in Kenya: https://www.youtube.com/watch?v=DMu9k2N0WMU.
f. Publications.
    - One plant health case (https://www.researchgate.net/publication/376069921_Papaya_Mealybug_in_Kenya_Identification_Management_and_Future_Outlook);
    - A study brief on PMB biocontrol of PMB and lessons learnt (https://www.researchgate.net/publication/379542644_Biocontrol_for_papaya_mealybug_lessons_learnt_from_Kenya)

g. 3 blogs:
    - https://blog.invasive-species.org/2023/12/01/scaling-up-the-fight-against-papaya-mealybug-pest-in-south-sudan/ - this blog was further publicised by international media outside the African continent (Scaling up the fight against papaya mealybug pest in South Sudan | Krishak Jagat).
    - https://www.cabi.org/news-article/fight-against-papaya-mealybug-in-kenya-stepped-up-with-agent-release-in-four-more-counties/
    - https://www.cabi.org/news-article/cabi-works-in-partnership-to-step-up-fight-against-pests-and-diseases-of-papaya-in-uganda/

3.2 Progress towards project Outputs

Output 1: The *A. papayae* parasitoid released and naturalized in East Africa for the sustainable biological control of papaya mealybug and protection of native insect biodiversity.

Field releases of parasitoids have been conducted on more than 250 farms across Kenya and Uganda, encompassing both new introductions/releases and augmentation activities. This has resulted in more than 1.3 million parasitoids released in these farms. To meet the growing demand for parasitoids, mass-rearing capacity was boosted from 5000 to over 100,000 parasitoids per month. Additionally, upgrades to the rearing facility in NARO have expanded production capacity and facilitated field releases. Furthermore, the construction of NEFRs (see 1.4) in selected farms has facilitated parasitoid establishment and enhanced efficacy, while also promoting natural enemies' abundance and diversity. Preliminary post-release studies have confirmed the establishment and spread of the parasitoids in Kenya and Uganda in addition to reduced PMB populations. In South Sudan, delays in parasitoid releases were due to security clearance issues and limited organized papaya farming (kitchen garden). Plans for releasing parasitoids in other crops affected by PMB, such as cassava and okra, are scheduled for Year 3. An ecological niche model has been developed to identify potential areas conducive to parasitoid establishment and spread in relation to potential PMB invasion areas. Notably, all operation regions in the three countries are suitable for both PMB and its parasitoid establishment. These findings will guide any scale out activities for field release in Y3.

Output 2: Capacity of crop inspectors, small-holder farmers, extension providers and the general public enhanced on in situ management of *A. papayae* on sustainable management of papaya mealybug and biodiversity conservation

Darwin partners in the three countries collaborated to provide training for inspectors, extension officers, and farmers on identifying PMB and other scale insects, as well as on biocontrol and conservation techniques, including *in-situ* production of PMB parasitoids. In the three countries, a total of 319 extension officers (102 female), 39 inspectors (12 females), and 297 farmers have been trained to date. Additionally, following a site selection activity in Kenya, approximately 361 farmers were reached. To further strengthen the capacity of these groups, various technical materials have been developed, including an extension training manual for the Integrated Management of PMB, a PMB technical brief, a photosheet for PMB identification, a papaya diseases and disorders pocket guide, and a pest management decision guide (PMDG) (Refer to 4.2). the project (with co-financing from PlantwisePlus) has facilitated the refurbishment of a parasitoid-rearing facility and trained technical staff at NARO further building capacity at the institution level.

Output 3: Scientific evidence-base generated on impacts of classical biological control of *A. papayae* on livelihoods and native insect biodiversity.

Preliminary post-release studies to assess the establishment and spread of the parasitoid, role of NEFRs in PMB management, have been conducted in Kenya and Uganda (Refer to output 1). Baseline reports and checklists for native insect and plant diversity have been completed for the three countries (refer to 1.2.). Socio-economic studies to assess impact on yield and income are planned for Y3. Data collection tools under development.

Output 4. Information on classical biocontrol of papaya mealybug and conservation biocontrol approaches to support natural pest regulation and better management of biodiversity packaged and disseminated to increase farmer knowledge and technology adoption

The implementing partners have developed a gender and communication strategy, with identified activities to promote the strategy among various stakeholders (refer to the gender strategy document). The strategy aims to support the integration of gender throughout the project's work by providing an overarching framework of principles and guidance for implementing tools that promote gender equity and women's empowerment. Additionally, technical materials aimed at a diverse audience have been created and disseminated. Specifically, this includes the development of two journal publications, three blogs, a technical brief, a pest management decision guide for PMB, a photosheet, and a pocket guide on papaya disorders (Refer to activity 4.2). Some of the published blogs have been further publicised by international media outside the African continent (Scaling up the fight against papaya mealybug pest in South Sudan | Krishak Jagat). During the review period, the project activities attracted interest from different groups. Notably, a delegation from DGIS and 30 participants of the GIZ-Eco-IPM workshop on Agro-ecological Innovation for smallholder pest management in Uganda, Malawi and Zambia were hosted at the NARO, Uganda and taken through the biocontrol processes including hands-on practical's, in their rearing facility and farmer field visit (refer to visit report from Uganda).

3.3 Progress towards the project Outcome

Year 2 of the project saw significant progress in enhancing the capacity of inspectors, extension service providers, and farmers in the implementing countries on various aspects of PMB classical biocontrol. Field release and in-situ production activities for the parasitoid were successfully carried out in Kenya and Uganda despite delays in acquiring the import permit, with efforts underway to achieve the same in South Sudan, where an import permit has already been acquired. The areawide releases of the parasitoid are expected to significantly reduce the use of pesticides and PMB populations, leading to high crop production and increased household income. All indicators still appear to be adequate, with some of them probably being exceeded by the end of the project, especially regarding the capacity-building activities of extension staff and farmers and mass releases. The success of the project is likely to have a positive impact on biodiversity conservation and crop production, demonstrating the effectiveness of biological

control as a sustainable and environmentally friendly method for PMB management. Socio-economic studies that are planned for Y3 will give insights into yield and income. The training given to extension officers, crop inspectors and farmers has already shown the benefits as they have supported the mass campaigns of PMB and its parasitoids and facilitated the alerts on parasitoid spread and the overall management of PMB.

3.4 Monitoring of assumptions

All assumptions remain valid and none of the listed risks have impacted the outcome level. However, the release of the parasitoid was delayed due to the delayed acquisition of import permits in Uganda at the output level. Similar delays occurred in South Sudan, but plans are in place to address them by expanding the focus beyond papaya crops to other economically important hosts (cassava and okra). In Kenya, where success has been observed, permission to release in five additional counties has been granted by the Kenya Standing Technical Committee on Imports and Exports (KSTCIE). Furthermore, there is increased farmer interest in participating in the program both within and outside the project area, with regions like Baringo receiving emergency approval in response to farmers' requests for PMB management support.

3.5 Impact: achievement of positive impact on biodiversity and poverty reduction

Sustainable management of papaya mealybug achieved in East Africa through biological control thereby enhancing livelihoods and protecting native insect biodiversity threatened by pesticide use.

By the end of the project, target groups will gain a better understanding of biodiversity issues related to PMB biocontrol. Relevant stakeholders will receive training in sustainable methods like classical biocontrol to manage PMB pests while promoting eco-friendly practices. The project aims to train relevant groups in biocontrol methods, including parasitoid use and in-situ natural enemy production (See field release and NEFR reports, study brief above). Chemical control, commonly used by farmers, poses risks to biodiversity and human health. Adopting biological control can mitigate these risks, offering sustainable pest management and higher yields. The project has already established baseline native insect biodiversity in three countries (see biodiversity reports) and an endline study will be conducted to evaluate change after intervention. Socio-economic data tools are being developed to assess yield and income impacts. Already farmer feedback is reporting positive PMB management and improved yield with some farmers returning to papaya farming after initially abandoning the crop due to PMB. This is expected to increase household income.

4. Project support to the Conventions, Treaties or Agreements

This project aligns with the CBD objective to conserve biodiversity by using Classical Biological Control (CBC) as an eco-friendly alternative to pesticides for managing invasive alien species (IAS). This project will contribute directly to articles 6 (*General Measures for Conservation and Sustainable Use*), 7 (*Identification and Monitoring*), 12 (*Research and Training*) and 13 (*Public Education and Awareness*) of the CBD. Several drivers of change to biodiversity have been recognised in the context of the CBD: Invasive species*; unsustainable agricultural development; chemical overload causing unacceptable loss of pollinators and other biodiversity* among others. The project objectives are to reduce these pressures on EA biodiversity, in line with the National Biodiversity Strategy and Action Plan objectives. To date, three baseline insect and plant biodiversity checklists and reports have been produced contributing to national targets on biodiversity in the three countries e.g. National Target 22 for South Sudan- *increase in the contribution of scientifically-based information into biodiversity decision-making process and management intervention*; National Target 21 for Uganda- *people are aware of the value of biodiversity and steps they can take to conserve and use it sustainably,* National target 5- *basic taxonomic information is packaged in user-friendly formats and widely disseminated, including use of school systems.*

Additionally, the project aims to achieve the Aichi Biodiversity Targets of three countries by identifying and prioritizing invasive alien species (IAS) and pathways, controlling or eradicating priority species, and implementing measures to manage pathways; and to address invasive species as a serious threat to native biodiversity in Kenya, South Sudan, and Uganda, as recognized in their National Biodiversity Strategy and Action Plans. The field releases conducted in the reporting period, have contributed to achieving National Target 14- *Invasive alien species (IAS) harmful to biodiversity, socio-economic development and human health are managed to prevent their introduction and establishment.* Further, in the reporting period, the project has trained crop inspectors, extension service providers, and farmers in the implementing countries to identify and manage PMB sustainably, which is a critical component of achieving these goals (Refer to training reports above). The technical materials produced (training manual, technical brief among others), which have been shared with partners will be a critical resource for the future. Additionally, the durable facilities like the parasitoid rearing facilities in NARO and CABI/KALRO will further enhance not just the PMB management but in-country capacity.

5. Project support for multidimensional poverty reduction

This project directly benefits papaya farmers affected by PMB in Kenya, Uganda, and South Sudan by implementing biocontrol measures against PMB, reducing pesticide usage. This reduction mitigates negative impacts on crop yields and smallholder debt, ultimately alleviating poverty. Moreover, decreased PMB infestation leads to improved crop yield, as evidenced by positive farmer feedback. Field reports indicate former papaya farmers returning to the trade after periods of PMB-induced abandonment, which is expected to boost income and reduce poverty levels. Parasitoid releases in Kenya have notably reduced pesticide usage, enhanced papaya yields, and safeguarded native biodiversity (Refer to the NEFR paper and study brief above). Additionally with increased abundance of natural enemies within farming systems, other pests are likely to be kept under check further improving crop production and household income. Over 250 farmers have benefited from these releases in Kenya and Uganda. Though empirical data collection is planned for Y3, field testimonies are already promising. For instance, post-release surveys show that the parasitoid has become established at Coastal Kenya, with parasitism rates of up to 53% after one release and up to 72% after the second release. Nearly 85% of farmers view the release of the biological control agent to manage the papaya mealybug positively, and most farmers (94%) support the biological control programme for papaya mealybug in their community. Further, capacity-building initiatives for PMB classical and conservation biological practices among inspectors, extension workers, and farmers will enhance sustainable pest management, ultimately benefiting papaya farmers.

6. Gender Equality and Social Inclusion (GESI)

Please quantify the proportion of women on the Project Board[1].	The chair of the Project Board is a woman
Please quantify the proportion of project partners that are led by women, or which have a senior leadership team consisting of at least 50% women[2].	Three of the project partners leads specifically NMK, KEPHIS and NARO are women, which comprises 50%

GESI Scale	Description	Put X where you think your project is on the scale

[1] A Project Board has overall authority for the project, is accountable for its success or failure, and supports the senior project manager to successfully deliver the project.

[2] Partners that have formal governance role in the project, and a formal relationship with the project that may involve staff costs and/or budget management responsibilities.

Not yet sensitive	The GESI context may have been considered but the project isn't quite meeting the requirements of a 'sensitive' approach	
Sensitive	The GESI context has been considered and project activities take this into account in their design and implementation. The project addresses basic needs and vulnerabilities of women and marginalised groups and the project will not contribute to or create further inequalities.	
Empowering	The project has all the characteristics of a 'sensitive' approach whilst also increasing equal access to assets, resources and capabilities for women and marginalised groups	X
Transformative	The project has all the characteristics of an 'empowering' approach whilst also addressing unequal power relationships and seeking institutional and societal change	

The project has developed an ambitious gender and communication strategy to ensure gender integration across project activities. Various initiatives have been outlined for different stakeholders to promote gender inclusivity in all project aspects across the participating countries. While there is room for improvement, significant progress has been made in Kenya and Uganda, whereas efforts are ongoing in South Sudan. Notably, recent extension officer training sessions in Kenya and Uganda saw the participation of 122 (47 women) and 33 (11 women) officers, respectively. During the site selection process, out of 361 farmers reached 147 were women. Additionally, at the decision-making level, the project's board comprises three women (50%), with a woman serving as the chair, achieving gender parity in representation.

7. Monitoring and evaluation

CABI leads the overall Monitoring and Evaluation process, ensuring that project activities are on track and outputs are delivered on time. The steering committee and project team convened once in person (refer to the review and planning meeting report) and virtually as needed to address any issues. During the review period, the logframe was revised and shared with the donor through a change request (Annex 4.34); however, no feedback was received on the proposed changes, and it was assumed that since these were minor, they were acceptable. Consequently, the attached logframe in this report reflects the updated version.

8. Lessons learnt

Throughout the reporting period, project partners across the three countries forged a robust collaboration, ensuring the successful execution of key project activities through continuous communication. The review meeting conducted during this period provided an excellent opportunity for reflection, assessment, and strategic planning. Furthermore, regular meetings between CABI and individual partner institutions facilitated the timely completion of technical and financial reports. In cases where delays arose due to institutional challenges, such as those encountered with NMK, NARO, or UoJ, CABI effectively managed their respective budgets to ensure project activities were still carried out. The collaborative approach adopted in Year 2 among the partners resulted in the successful implementation of key activities across all three countries, particularly in training, site selection, and biodiversity studies. Moving forward, it is imperative to streamline contract negotiations with partners in advance to mitigate potential delays in project activities.

9. Actions taken in response to previous reviews (if applicable)

During the review period, project partners held a review meeting to address various objectives, including reviewing feedback from the donor. Consensus was reached among partners to

enhance implementation in the second year, emphasizing the inclusion of documentary evidence to substantiate report claims. Consequently, this report incorporates previously missing evidence, such as the inception meeting report, biodiversity reports, revised logframe, training reports, extension officers' IPM training manual. Additionally, supporting documents included in this report comprise the gender and communication strategy, PMB technical brief, pest management decision guide, and papaya disease pocket guide. Links to published papers, blogs/news pieces, and the project webpage are provided, along with details of matched funding. The donor comment on the direction of the project was responded to during the half-year report submission.

10. Risk Management

Risk register is attached as part of this report (Annex 4.35).

10. Sustainability and legacy

The project has gained recognition within the scientific community as it has received support from key national institutions responsible for agriculture and biodiversity. For example, 39 crop inspectors and over 300 extension staff have been trained in PMB identification and biocontrol, most of whom are permanent staff in government institutions in these countries, which ensures the project's long-term impact. The engagement of extension services and farmers through outreach activities, together with the publication of various blogs and news pieces has been picked by international media outside the continent. CABI has developed a dedicated project webpage (https://www.cabi.org/projects/biocontrol-of-papaya-mealybug-in-east-africa/). Further, through the construction of NEFRs in farmers' fields, there is gradual sustainability building and project exit. Additionally, the publication of journal articles and study brief (see previous section) has increased the Darwin visibility in the scientific space. The proposed original exit strategy is thus still largely valid. Further, during the reporting period, a delegation from DGIS visited parasitoid rearing facility at NARO and farmers' fields in Uganda where they were taken through the quarantine procedures and field activities under the DI project. Additionally, participants of the GIZ-EcoPM workshop on Agro-ecological Innovation for smallholder pest management in Uganda, Malawi and Zambia visited the rearing facilities where the project team took them through the processes and steps of PMB and parasitoid rearing.

11. Darwin Initiative identity

The Darwin Initiative has been acknowledged in all meetings, training sessions and materials and blogs. The link to the DI website is displayed on the project-dedicated page hosted by CABI (https://www.cabi.org/projects/biocontrol-of-papaya-mealybug-in-east-africa/). All presentations, documents, training manuals, and teaching aids used in the project feature the Darwin Initiative logo. The project has a distinct identity that is separate from CABI's papaya mealybug work led by the PlantwisePlus program. There have been deliberate efforts to raise awareness to the extension officers and inspectors about Darwin during training. The project has also been featured on the Darwin Website news (Conserving insect biodiversity).

12. Safeguarding

Has your Safeguarding Policy been updated in the past 12 months?	Yes
Have any concerns been reported in the past 12 months	No
Does your project have a Safeguarding focal point?	Yes/[redacted] Global Operations [redacted]
Has the focal point attended any formal training in the last 12 months?	No [Informal training, Informal training, following the update of the Safeguarding policy. We have also visited the partner institutions and ensured the adherence to the safeguarding policies]

What proportion (and number) of project staff have received formal training on Safeguarding?	Past: 75% [0] Planned: 25% [0]
Has there been any lessons learnt or challenges on Safeguarding in the past 12 months? Please ensure no sensitive data is included within responses. In the past 12 months, the project team have consistently upheld their institutional safeguarding policies without encountering any significant challenges, ensuring the safety and well-being of all individuals involved. There were concerns that the anti-homosexuality act enacted in Uganda in 2023 would pose a risk to project implementation, however this did not materialize or affect any project beneficiaries.	
Does the project have any developments or activities planned around Safeguarding in the coming 12 months? If so please specify. In the coming 12 months, we plan to implement additional sensitization sessions for stakeholders to reinforce our commitment to safeguarding, ensuring ongoing compliance and effectiveness in our project activities.	
Please describe any community sensitisation that has taken place over the past 12 months; include topics covered and number of participants. None.	
Have there been any concerns around Health, Safety and Security of your project over the past year? If yes, please outline how this was resolved. None	

13. Project expenditure

Table 1: Project expenditure during the reporting period (1 April 2023 – 31 March 2024)

Project spend (indicative) since last Annual Report	2023/24 Grant (£)	2023/24 Total Darwin Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs	[redacted]			Less staff resources, project staff resources optimal.
Consultancy costs				No consultancy costs
Overhead Costs				Overhead built into staff costs, within allowable +/- 10% of budget
Travel and subsistence				Higher travel costs due to inflation, but within +/- 10% of budget
Operating Costs				Within +/- 10% of budget
Capital items				
Others				Higher costs due to inflation Within +/- 10% of budget
TOTAL	**168,289.00**	**168,234.65**	**-0.03%**	**Overall, within the +/- 10% of budget**

Table 2: Project mobilised or matched funding during the reporting period (1 April 2023 – 31 March 2024)

	Secured to date	Expected by end of project	Sources
Matched funding leveraged by the partners to deliver the project (£)	CABIs PlantwisePlus scale out (2024-2030) programme, to mass release the parasitoid in areas the Darwin project is not working	[redacted]	Multi-donors of EU, SDC, DGIS and FCDO
	Managing scale insects in fresh fruits in East Africa Project: to improve cross-border inspection, regulations and practices between Kenya and Uganda	In kind contribution estimated at [redacted]	Standards and Trade Development Facility
Total additional finance mobilised for new activities occurring outside of the project, building on evidence, best practices and the project (£)		[redacted]	

11. Other comments on progress not covered elsewhere

None

12. OPTIONAL: Outstanding achievements or progress of your project so far (300-400 words maximum). This section may be used for publicity purposes.

A delegation from the FCDO led by Sian Rasdale, Deputy Director, Global Science Department, visited the CABI/KALRO facility in Kenya and were apprised of the papaya mealybug biocontrol work (FCDO officials impressed with CABI's steps in partnership to help ensure greater food security in Africa). Similarly, a delegation from DGIS visited the project activities in Uganda and praised the efforts of the project to manage the pest using solutions that conserve biodiversity (Annex 4.34).

File Type (Image / Video / Graphic)	File Name or File Location	Caption including description, country and credit	Social media accounts and websites to be tagged (leave blank if none)	Consent of subjects received (delete as necessary)
				Yes / No
				Yes / No
				Yes / No

I agree for the Biodiversity Challenge Funds to edit and use the following for various promotional purposes (please leave this line in to indicate your agreement to use any material you provide here).

Annex 1: Report of progress and achievements against logframe for Financial Year 2023-2024

Project summary	Progress and Achievements April 2023 - March 2024	Actions required/planned for next period
Impact: *Sustainable management of papaya mealybug achieved in East Africa through biological control thereby enhancing livelihoods and protecting native insect biodiversity threatened by pesticide use*	Increased understanding of PMB biocontrol through training of relevant groups Sustainable management of PMB through field releases of A. papayae Preliminary post release monitoring in the release has shown increase in number of other N.Es after pesticide withdrawal (See NEFRs paper). Data to compared with the baseline biodiversity studies. Proper post release study not begun but farmer report shows a reduction in pest population after parasitoid release. Additionally, field reports show farmers returning to papaya farming after periods of abandonment due to PMB. Post-release assessments planned for Y3.	
Outcome: The A. papayae parasitoid released and naturalized in East Africa for the sustainable biological control of papaya mealybug and protection of native insect biodiversity		
Outcome indicator 0.1: Diversity of native insects at the selected "biological control learning sites" established in the three project countries by Year 1 (baseline) and Year 3 (end of project).	Three (3) baseline insect and plant biodiversity reports and checklists developed for Kenya, South Sudan and Uganda (see 1.4)	a. Planned endline studies planned for by end of Y3 in the three countries
Outcome indicator 0.2: Number of hectares (ha) established with the *A. papayae* parasitoid.	Field release of *A. papayae* in 207 farms (~200ha) in Kenya; 14 farms (~10ha) in Uganda (See reports section 3.1)	a. Mass release in Kenya, Uganda and South Sudan in Y3 b. Post-release studies to establish spread/dispersal in Kenya and Uganda
Outcome Indicator 1.2: Number of people with improved knowledge about classical biocontrol for papaya mealybug	319 extension officers (102 female), 39 inspectors (12 females), and 297 farmers trained in Kenya, Uganda and South Sudan. In addition, 361 farmers reached in the site selection activity in Kenya (to be trained in the scale-out phase in Y3) (Refer to	a. Scale up the training of extension officers, crop inspectors, farmers and community facilitators in all three countries
Outcome Indicator 1.3: % of expenditure reduction per ha on pesticides to control papaya mealybug on smallholder farms.	Not begun; Post release socio-economic studies planned for Y3	a. Undertake socio-economic studies; data collection under development

Outcome Indicator 1.4: % of smallholder farmers with improved papaya yield by year 3.	Not begun; Post release socio-economic studies planned for Y3	a. Undertake socio-economic studies; data collection under development
Outcome Indicator 1.5: 20% reduction in the occurrence of PMB in the target countries by year 3	Preliminary post-release observations show a reduction in the PMB population in release sites.	a. Conduct post- release assessment in Y3
Output 1: The *A. papayae parasitoid* released and naturalized in East Africa for the sustainable biological control of papaya mealybug and protection of native insect biodiversity		
Output indicator 1.1: Over 1300000 of *A. papayae* individuals produced and released in the three countries by year 3	Mass reared and released over 1.2 million parasitoids in Kenya and Uganda.	a. Mass rearing and field release in Kenya and Uganda b. Introduction and field release in South Sudan
Output indicator 1.2: 240 farmers (50 women) practicing *in-situ* conservation of *A. papayae parasitoid* for augmentative field releases by year 2.	Kenya = 298 (72 Female) trained in Kenya; 20 farmers established NEFRs; Training of farmers in Uganda only involved those in the pilot phase (14 farmers) of parasitoid releases; 4 established NEFRs. Structured training planned for Y3.	a. Scale up training of farmers in Kenya in the extra release counties, Uganda and South Sudan.
Output 2: Capacity of crop inspectors, small-holder farmers, extension providers and the general public enhanced on *in situ* management of *A. papayae on* sustainable management of papaya mealybug and biodiversity conservation		
Output indicator 2.1: 120 crop inspectors and researchers (at least 40% women) trained on biological control-biodiversity conservation nexus for papaya mealybug and *A. papayae* parasitoid by 2025	48 crop inspectors in Kenya, Uganda and South Sudan have been on PMB biocontrol	a. Scale up the training of inspectors in the three countries
Output indicator 2.2: 300 extension workers and community facilitators (50% women) have increased ability on *in-situ* conservation of *A. papayae*, to support the process of naturalization by year 3.	319 extension officers (102 female) trained in Kenya, Uganda and South Sudan	a. Scale up training of extension workers and community facilitator in the three countries
Output 3: Scientific evidence-base generated on impacts of classical biological control of A. papayae on livelihoods and native insect biodiversity		
Output indicator 3.1: Evidence of impacts of the classical biological control agent on non-target scale insects documented by Year 2.5	Not begun	a. Conduct post-release assessment on impact on non-target scale insects; survey tool under development b. Publish findings c. Present in conference.

Output indicator 3.2: Evidence on effect of pesticide use on native insect biodiversity, disaggregated by; abandoned and severely infested fields; infested fields but yielding; fields with and without parasitoids by Year 3.	Post- release monitoring in the Release sites has reported increase in other N.Es e.g. lady bird beetles, parasitic wasps (*P. mexicana*) etc. after pesticide withdrawal; a NEFR study with similar parameters showed increased abundance in natural enemies and increased parasitoid efficacy in Kenya	a. Replicate the study in Uganda and South Sudan.
Output indicator 3.3: Evidence on impacts of the classical biological control approach on the population of the papaya mealybug and crop infestation documented by Year 3	One study brief published (DI & PlantwisePlus). Though farmer reports show reduction in pest population; farmer testimonials confirm reduction in PMB infestation in the release sites.	a. Conduct post-release assessment in the treated sites b. Publish findings c. Conference presentations
Output indicator 3.4: Evidence on effects of *A. papayae* biological control on yield and incomes of smallholder households (30% women-owned) documented in year 2.5 and Year 3	Not began. Though farmer reports show return to papaya farmer after periods of abandonment due to PMB. That's expected to increase yields and/or income	a. Conduct socio-economic studies in release areas
Output indicator 3.5: Evidence on the native insect biodiversity post-release of *A. papayae* documented to demonstrate the impacts of the classical biological control programme by Year 2.5.	3 baseline reports and plant and invertebrates' checklists completed for KE, SS and UG.	a. Conduct endline assessments in the biological learning sites
Output 4. Information on classical biocontrol of papaya mealybug and conservation biocontrol approaches to support natural pest regulation and better management of biodiversity packaged and disseminated to increase farmer knowledge and technology adoption		
Output indicator 4.1: About 2000 smallholder farmers are (F=at least 40%) received the various gender-responsive communication on classical biocontrol of papaya mealybug by Year 3.	Gender and communication strategy developed; activities for gender integration in project activities identified vs relevant stakeholder	a. Publicise the strategy to reach scale b. Scale up the dissemination of the IEC materials to farmers
Output Indicator 4.2: 300 extension officers receive the various gender-responsive communication on classical biocontrol of papaya mealybug by Year 3	More than 300 extension officers trained and given gender-responsive technical materials including technical brief, PMDG, photosheets etc.	a. Scale up the dissemination of the IEC materials to extension officers
Output indicator 4.3: 100 other stakeholders in project countries who have received the various gender-responsive communication on classical biocontrol of papaya mealybug by Year 3	Not begun, but the stakeholders identified in the strategy to be prioritised *viz.* academia, policy makers, private sector etc	a. Scale up the dissemination of the IEC materials to other stakeholders.
Output Indicator 4.4: 10 information products (media articles, policy brief, impact stories, fact sheets, journal articles) targeting different stakeholders developed and disseminated by Year 3	Developed: i. One (1) Training manual completed. ii. Three (3) blogs published (some picked up international media) iii. One PMB technical brief developed iv. One PMDG developed v. Papaya disorders printed vi. One photosheet developed vii. Gender & Communication Strategy	a. Published more products b. Disseminate developed products

Annex 2: Project's full current logframe as presented in the application form (unless changes have been agreed)

Project summary	SMART Indicators	Means of verification	Important Assumptions
Impact: Sustainable management of papaya mealybug achieved in East Africa through biological control thereby enhancing livelihoods and protecting native insect biodiversity threatened by pesticide use	Indicator 1.1a: 20% hectares of land have increased diversity of native insect enemies by year 3. Baseline 2019=0 Milestone 2023=5% Target 2025=20% **Indicator** 1.1b: 20% reduction in papaya yield losses associated with papaya mealybug by year 3. Baseline 2019=57% Milestone 2023=30% Target value 2025= 20% **Indicator** 1.1c: 40% change of income per ha among papaya farmer by year 3. Baseline 2019= 2,911 USD Target 2025= 1737 USD **Indicator 1.1d**. 20% reduction in the occurrence of PMB in the target countries by year 3 Baseline: 80% Milestone 2023 Target 2025: 60%	• End of project evaluation report • Biodiversity assessment report in Year 3	• The local environmental factors for Uganda and South Sudan are similar to Kenya (no drastic change to curtail the spread of the parasitoids) • Weather patterns are conducive to papaya crop production • Risk: Covid-19 restrictions remain stable to enable people to move and gather.
Outcome: *East Africans will have an increased regional capacity to manage papaya mealybug using climate-smart biocontrol thereby reducing the risk of native insect biodiversity loss and increasing incomes of farmers*	**Indicator 1.1.1**: Diversity of native insects at the selected "biological control learning sites" established by Year 1 (baseline) and Year 3 (end of project).	• Mid-term and end of project assessment of papaya farmers to establish presence, or absence of the parasitoid • Impact assessment report on the household and community benefits of the project. • Farmer reports and Country records on frequency of pesticide use and associated expenditure.	• Farmers are willing to take up the use of classical biological control for papaya mealybug and reduce pesticide use.
Output 1: The *A. papayae parasitoid* released and naturalized in East Africa for the sustainable biological control of papaya mealybug and protection of native insect biodiversity	**1.1:** Diversity of native insects at the selected "biological control learning sites" established in the three project countries by Year 1 (baseline) and Year 3 (end of project). **1.2**: Over 300000 of *A. papayae* individuals produced and released in the three countries by year 3. Baseline=5000	**1.1**: Museum collection and baseline report of native insects at the "biological control learning sites" in year one and year 3 **1.2:** Records of the number of *A. papayae* reservoirs set up on farmers for *A.papayae*	• Multiple open data sources are available and accessible on parasitoid distribution for ecological modelling. • Permits for release of the parasitoid are obtained in a timely manner from the government agencies in charge

	Milestone 2023=120000 Target 2025=300000 **1.3:** 240 farmers (50 women) practicing *in-situ* conservation of A. papaya *parasitoid* for augmentative field releases by year 2. Baseline=0 Milestone 2023=10 Target 2025 =240 (50 women)	parasitoid mass production in Kenya, South Sudan and Uganda **1.3:** Post-release assessments report with a list and country maps of georeferenced farms where *A. papayae* is released and established	
Output 2: Capacity of crop inspectors, small-holder farmers, extension providers and the general public enhanced on in situ management of A. papayae on sustainable management of papaya mealybug and biodiversity conservation	**Indicator 2.1:** 120 crop inspectors and researchers (at least 40% women) trained on biological control-biodiversity conservation nexus for papaya mealybug and *A. papayae* parasitoid by 2025 Baseline =0 Milestone 2023 =10 Target 2025=120 **Indicator 2.2:** 300 extension workers and community facilitators (50% women) have increased ability on *in-situ* conservation of *A. papayae*, to support the process of naturalization by year 3. Baseline=0 Milestone 2023=100 Target 2025=300	• Monitoring reports on capacity, knowledge, skills of crop inspectors, extension workers and community facilitators on papaya mealybug management and biodiversity conservation • Reports on parasitoid mass rearing, and training attendance lists • Report of farmers trained on *in situ* production of *A. papayae* and attendance lists	• Equipment for setting up field reservoirs at farmers' fields is readily available. • Risk: Covid-19 persists to restrict gatherings necessary to conduct practical in-person farmer trainings.
Output 3: Scientific evidence-base generated on impacts of classical biological control of *A. papayae* on livelihoods and native insect biodiversity	**3.1**: Evidence of impacts of the classical biological control agent on non-target scale insects documented by Year 2.5. **3.2**: Evidence on effect of pesticide use on native insect biodiversity, disaggregated by; abandoned and severely infested fields; infested fields but yielding; fields with and without parasitoids by Year 3. **3.3:** Evidence on impacts of the classical biological control approach on the population of the papaya mealybug and crop infestation documented by Year 3. Indicator 3.4: Evidence on effects of *A. papayae* biological control on yield and incomes of smallholder households (30%	• Scientific publication on the impacts of the parasitoid on non-target scale insects and • other native beneficial insects • Scientific publication on the post-release impact of the classical biological control programme on PMB infestation • Scientific publication on the socio-economic impact of the parasitoid release on yield, • pesticide use and income (both papaya and other insect pollinated crops • Baseline and final report and maps showing distribution and abundance of native insect • species in papaya agro-ecologies	• Smallholder farmers and extension workers are willing to participate in the surveys

	women-owned) documented in year 2.5 and Year 3. Indicator 3.5: Evidence on the native insect biodiversity post-release of *A. papayae* documented to demonstrate the impacts of the classical biological control programme by Year 2.5.	• Museum collections of • native insect species from the release sites in space and time	
Output 4. Information on classical biocontrol of papaya mealybug and conservation biocontrol approaches to support natural pest regulation and better management of biodiversity packaged and disseminated to increase farmer knowledge and technology adoption	**Indicator 4.1:** About 2000 smallholder farmers are (F=at least 40%) received the various gender-responsive communication on classical biocontrol of papaya mealybug by Year 3. Baseline=0 Milestone 2023=30 Target 2025=2000 (F=at least 40%) **Indicator 4.2:** 300 extension officers receive the various gender-responsive communication on classical biocontrol of papaya mealybug by Year 3 Baseline=0 Milestone2023=30 Target 2025=300 **Indicator 4.3:** 100 other stakeholders in project countries who have received the various gender-responsive communication on classical biocontrol of papaya mealybug by Year 3 Baseline=0 Milestone 2023=50 Target 2025=100 Indicator 4.4. 10 information products (media articles, policy brief, impact stories, fact sheets, journal articles) targeting different stakeholders developed and disseminated by Year 3. Baseline=0 Milestone 2023=3 Target 2025 =10	• Manual documenting the best practices of pest control and biodiversity conservation • Blogs, social media, articles, Publications, radio programmes, fact sheets, photo sheets, pamphlets, brochures; project progress and final reports; feedback from stakeholders in the final report • Mid-term M&E report on pesticide use, Training reports and attendance sheets for workshops Insect mass rearing records of parasitoids produced/week	• National stakeholders are willing to collaborate in providing information. • Political and public health concerns such as Covid-19 are suitable for holding mass awareness activities.

Activities

1.1: Conduct ecological niche modelling to evaluate the environmental suitability for *A. papayae* across East Africa to identify potential release areas, Y1 Q3

1.2: Undertake a baseline study at selected biological control learning sites to determine the native insect biodiversity under farmers practices, Y1, Q3

1.3: Conduct area-wide releases of *A. papayae* in Kenya, South Sudan and Uganda using hand releases and also deploying technology such as drones and landscape scale, Y3 Q3

1.4: Establish *A. papayae* reservoirs on farmers' fields for parasitoid mass production *in situ* for augmentative field releases during naturalization, Y1 Q3; Y2 Q2 and Y3 Q3

1.5: Conduct monitoring to determine post-release establishment and parasitoid efficacy as well as expansion outside the release areas, Y1 Q3; Y2 Q2; Y3 Q1, Y4 Q4

2.1: Train crop inspectors in identification of *papaya mealybug* and related scale insects, the *A. papayae* parasitoid and the biological control-biodiversity conservation nexus, Y1 Q2; Y2 Q1; Y3 Q4

2.2: Train extension workers and community facilitators on conservation of *A. papayae* in the field, to support the process of naturalization, Y1 Q3; Y2 Q2, Y3 Q1, Y4 Q3

2.3: Train farmers on *in situ* production of *A. papayae* in their farms, Y3 Q3

3.1: Undertake surveys to establish the effect of pesticide use on native insect biodiversity, comparing fields with and without the parasitoid, and fields with farmers pesticide practices, Y1 Q1; Y1 Q3; Y2 Q1; Y2 Q3; Y3 Q1; Y3 Q3

3.2: Conduct socio-economic studies to determine the impacts of the CBC approach on the population of papaya mealybug and crop infestation, Y3 Q3

3.3: Undertake surveys to assess the impacts of *A. papaya*e biological control on yield and incomes of smallholder households, Y3 Q3

3.4: Generate an inventory of native insect biodiversity pre-and post-release of *A. papayae* to determine the positive impacts of the classical biological control programme on insect biodiversity; Y1 Q1; Y1 Q4; Y2 Q3; Y3 Q2

3.5: Conduct surveys to establish impacts of the classical biological control agent on non-target scale insects, Y3 Q3

4.1: Develop an effective, gender responsive communication plan, integrating multi-channel communication approaches appropriate for reaching men and women smallholder farmers, Y1 Q3

4.2: Produce and disseminate different information products on targeting different stakeholders on dual purpose - pest control and biodiversity conservation nexus, Y4 Q4

Annex 3: Standard Indicators

Table 1: Project Standard Indicators

DI Indicator number	Name of indicator	Units	Disaggregation	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project
DI-D01	Number of hectares (ha) established with the A. papayae parasitoid.	Acres	Farms	172	78		250 (study in Y3 beyond the release sites to determine total ha with the agent)	75000ha
DI-D01	Production capacity of A. papayae increased and released in the three countries	None	None	684750	~900000		~1500000	3000000
DI-D01	Proportion of pesticide expenditure cost for PMB control	Proportion	Households	0	Over 200; all the farmers engaged participating in PMB biocontrol withdrew pesticide use		>100	Reduced by 50%
	% of smallholder farmers with improved papaya yield by year 3	Proportion	Households	0	TBD		0 (post release assessment for Y3)	15000
	150 (50 women) farmers trained on in situ production of A. papayae in their farms by Year 2	People	Men Women	118 96	73 24		191 120	150 (50 women)
DI-A01	Indicator 2.1.1: At least 10 crop inspectors (50% women) trained in identification of papaya mealybug, A. papayae parasitoid and have an understanding of the biological control-biodiversity conservation nexus by Year 1	People	Men women	6 18	48 17		56 35	120 (40% women)
	Indicator 2.1.2: At least 100 extension workers and community facilitators (50% women) trained on mass rearing of A. papayae in the field, to support the process of naturalization by Year 1.5	People	Men Women	79 55	122 63		201 118	100 (50%)

DI Indicator number	Name of indicator	Units	Disaggregation	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project
DI-C19	At least 10 (media articles, policy brief, impact stories, fact sheets, journal articles) information products targeting different	Number	None	2	2		4	10

Table 2 : Publications

Title	Type (e.g. journals, best practice manual, blog post, online videos, podcasts, CDs)	Detail (authors, year)	Gender of Lead Author	Nationality of Lead Author	Publishers (name, city)	Available from (e.g. weblink or publisher if not available online)
• Papaya Mealybug in Kenya: Identification, Management, and Future Outlook*	Plant health case	Makale F., Kansiime M., Rwomushana I (2023)	M	Kenyan	CABI Plant health Cases	• https://doi.org/10.1079/planthealthcases.2023.0018
• Biocontrol for papaya mealybug: lessons learnt from Kenya*	Study brief	Opisa S, Constantine K. (2024)	F	Kenyan	CABI	• https://dx.doi.org/10.1079/CABICOMM-62-8176
• Scaling-up the fight against papaya mealybug pest in South Sudan*	Blog	Makale F., Rware H., (2023)	M	Kenyan	CABI	• https://blog.invasive-species.org/2023/12/01/scaling-up-the-fight-against-papaya-mealybug-pest-in-south-sudan/
• Fight against papaya mealybug in Kenya stepped up with agent release in four more counties*	News article	Rwomushana I (2023)	F	Kenyan	CABI	• https://www.cabi.org/news-article/fight-against-papaya-mealybug-in-kenya-stepped-up-with-agent-release-in-four-more-counties/
• CABI works in partnership to step up fight against pests and diseases of papaya in Uganda*	News piece	Makale F., Rware H., (2023)	M	Kenyan	CABI	• https://www.cabi.org/news-article/cabi-works-in-partnership-to-step-up-fight-against-pests-and-diseases-of-papaya-in-uganda/

Annex 4: Onwards – supplementary material (optional but encouraged as evidence of project achievement)

Annex 4.1: Project Inception Workshop report, 29th June – 1st July 2022, Mombasa, Kenya

Annex 4.2: Review and Planning Meeting Report, 5-7. September.2023, Kampala, Uganda

Annex 4.3: Review and Planning Meeting Report, 17. April.2024, Kwale, Kenya

Annex 4.4: Uganda parasitoid import permit

Annex 4.5: South Sudan parasitoid import permit

Annex 4.6a: Farmers training and mass release of Acerophagus papayae in Lungalunga and Msambweni Sub counties

Annex 4.6b: Papaya mealybug Classical Biological Control Stakeholders awareness meeting in Machakos, Makueni, Embu and Tharaka Nithi counties

Annex 4.7: Agricultural extension officers and Crop inspectors Training- Western Equatoria State, South Sudan

Annex 4.8: Training of Extension officers on Classical Biological Control of the Papaya Mealybug (PMB) in Uganda (21st and 22nd February 2024) at the National Agricultural Research Laboratories Kawanda

Annex 4.9a: Training of national staff on mass rearing of papaya mealybug (PMB) and its parasitoid Acerophagus papayae under laboratory conditions

Annex 4.9b: Back to office report on the Training visit on papaya mealy bug (Paracoccus marginatus and its parasitoid Acerophagus papayae at CABI –Kenya, 17th – 21st July 2023

Annex 4.9c: Dissemination of PMB information to stakeholders for purpose of pest control and biodiversity

Annex 4.10: Training manual: Integrated management of Papaya mealybug (Paracoccus marginatus) and other Papaya pests in East Africa

Annex 4.11: Papaya mealybug: A Technical Brief - Description, Identification and Sustainable Management Strategies in Kenya

4.12: Gender and Communication Strategy: Protecting biodiversity through biocontrol of papaya mealybug in East Africa

4.13: Manuscript draft: Potential distribution of Acerophagus papayae, a parasitoid of the papaya mealybug (Paracoccus marginatus), across Africa

4.14a: Invertebrate Diversity in Pawpaw Farms Infested with Papaya Mealybugs in Tharaka Nithi and Embu counties, Kenya, December 2022

4.14b: Invertebrate Diversity in Pawpaw Farms Infested with Papaya Mealybugs in Tharaka Nithi and Embu counties, Kenya, December 2022

4.15a: Invertebrate Diversity in Pawpaw Farms Infested with Papaya Mealybugs in Kayunga, Luwero and Mukono Districts of Uganda: A Pre-parasitoid Release Assessment- February 2023

4.15b: Survey of Plant Diversity in Pawpaw Farms Infested with Papaya Mealybugs in Kayunga, Luwero and Mukono Districts of Uganda: A Pre-parasitoid Release Assessment- February 2023

4.16a: Invertebrate Diversity in Pawpaw Farms in Gondokoro Island, Nesitu and Rejaf East areas, in South Sudan

4.16b: Plant Diversity in Pawpaw Farms in for Gondokoro Island, Nesitu and Rejaf East areas in South Sudan-October 2023

4.16c: Plant Diversity in Pawpaw Farms in for Gondokoro Island, Nesitu and Rejaf East areas in South Sudan-October 2023

4.17a: Protocol for Mass-rearing, field release and post release monitoring of Acerophagus papayae Parasitoid of Papaya Mealybug, Paracoccus marginatus at the Coastal counties of Kenya

4.17b: Protocol for Mass-rearing, Field Release, and Post-release Monitoring of Acerophagus papayae, a Parasitoid of Papaya Mealybug (Paracoccus marginatus) in Uganda

4.18: Farmer training, mass release of Acerophagus papayae and post release data collection at Malindi, Kisauni, Nyali and Likoni Sub counties

4.19: Release of parasitoids in Mukono and Kayunga districts

4.20: Assessment of Acerophagus papayae establishment in papaya fields after first release: A Post-Release Field survey in Kayunga and Mukono

4.21: Establishment of Acerophagus papayae in release sites (Kayunga, Mukono, Luwero, Wakiso) and its spread in non-release sites in Uganda

4.22a: Approval for parasitoid release in Kenya – New Counties

4.22b: Approval to release at Baringo County

4.23a: National task force review of the dossier for importation of the parasitoid Acerophagus papayae for biological control on Papaya mealybug (Paracoccus marginatus) in Uganda

4.23b: Report for the National Taskforce Meeting – Uganda

4.24: Training on Mass rearing of papaya mealybug and its parasitoid under lab conditions and parasitoid field releases for Uganda partners

4.25: Assessment of establishment and recovery Acerophagus papayae at the release sites

4.26: Establishment of natural enemies' field reservoirs (NEFRs) against the papaya mealybug in the three coastal counties of Kenya; Final report

4.27: Natural Enemies Field Reservoirs (NEFRs) in Kilifi, Kwale and Mombasa counties, 13th to 30th June 2023

4.28: Natural Enemies Field Reservoirs (NEFRs) in Kilifi, Kwale and Mombasa counties, 28th May to 4th June 2023

4.29: Manuscript submitted to Biocontrol Journal: Unleashing Nature's Defenders: Farmer-Managed Natural Enemies Field Reservoirs (NEFRs) enhance management of the invasive Papaya Mealybug (Paracoccus marginatus) in Coastal Kenya

4.30: Mass-release and post-release studies of Acerophagus papayae on biodiversity of PMB natural enemy complex within papaya farms at the coastal counties

4.31: Technical report showing spread of parasitoid release sites in Uganda

4.32: Papaya Mealy Bug (PMB) Photo guide: Leaf, Stem and Fruit Damage

4.33a: Papaya mealybug Classical Biological Control Stakeholders awareness meeting in Machakos, Makueni, Embu and Tharaka Nithi counties

4.33b: Papaya mealybug parasitoid Site Selection in Machakos

4.34: Change request email to Darwin Initiative

4.35: Biodiversity Challenge Funds Risk Framework Template

4.36: Sharing of PMB activities with the Monitoring mission of CABI projects in Uganda (Mukono and Kayunga) by Netherlands, Directorate General for International Cooperation (DGIS),1st February 2024

Checklist for submission

	Check
Different reporting templates have different questions, and it is important you use the correct one. Have you checked you have used the **correct template** (checking fund, type of report (i.e. Annual or Final), and year) and **deleted the blue guidance text** before submission?	x
Is the report less than 10MB? If so, please email to BCF-Reports@niras.com putting the project number in the Subject line.	x
Is your report more than 10MB? If so, please discuss with BCF-Reports@niras.com about the best way to deliver the report, putting the project number in the Subject line.	x
Have you included means of verification? You should not submit every project document, but the main outputs and a selection of the others would strengthen the report.	x
If you are submitting photos for publicity purposes, do these meet the outlined requirements (see Section 16)?	x
Have you involved your partners in preparation of the report and named the main contributors	x
Have you completed the Project Expenditure table fully?	x
Do not include claim forms or other communications with this report.	