Rice mealybug (*Brevennia rehi*): a potential threat to rice in a long-term rice-based conservation agriculture system in the middle Indo-Gangetic Plain

The middle Indo-Gangetic Plain (MIGP) of India covering eastern Uttar Pradesh and Bihar is endowed with rich and diverse natural resources (land, water and environment), but low productivity and income. Rice-based cropping systems have maximum coverage of net sown area (9.64 m ha) in the MIGP[1]. Wheat, mustard, potato, maize and pulses are the major crops grown in rotation with rice. Rice–wheat system is extensively practised by the farmers of the region. This system requires high inputs in terms of machinery, nutrients, water and agro-chemicals. Unlike the northwestern part of the IGP (Trans and Upper IGP), the rice–wheat system of the MIGPs are less mechanized/labour-intensive due to small and fragmented land holdings and resource-poor farmers[2]. The total factor productivity index of the crops was reported to decline from 1.4% in Trans IGP to 0.43% in the MIGP[2]. Thus, the technological innovations along with socio-economic and policy reforms are the major challenges to sustain increase in productivity of rice-based production systems in the MIGP. There is a need to develop technologies for sustainable intensification and diversification of the rice–wheat system, including tillage and crop establishment options.

Traditional crop establishment methods in rice-based cropping systems (puddling and transplanting in rice and repeated tilling of soil in subsequent crops before sowing) are water-, labour- and energy-intensive, which are becoming increasingly scarce and expensive[3]. The conventional system of crop establishment not only increases the cost of production and deteriorates soil health but also delays sowing of subsequent crops, resulting in lower crop yields and system productivity. Wheat yields are reported to be reduced by 8% when grown after puddle transplanted rice in comparison to wheat grown after direct-seed rice under unpuddled condition[4]. Conventionally grown rice–wheat also leads to depletion of soil organic carbon in the eastern IGP[5]. Unsustainable use of land in tillage-based conventional rice–wheat system has resulted in declining the factor productivity due to soil organic matter depletion[6], soil structural degradation[7], soil erosion[8], reduced water infiltration[9], surface crusting[10], soil compaction[11], etc.

Conservation agriculture (CA) based on the three linked principles of minimum mechanical disturbance of the soil, permanent organic cover of the soil surface, and crop diversification, is an approach to manage agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. The adoption of no-till (NT) wheat in rice–wheat system in the MIGP is increasing due to technological benefits and Government support, but no adoption of permanent NT systems and full CA. Despite several benefits of NT, severe weed infestation continues to be a major problem in its adoption, especially in NT direct-seeded rice (NTDSR) because of simultaneous emergence of rice and weeds, and absence of standing water at the early stages of the crop to suppress weed growth[12]. In addition to direct yield loss by competing with crops for various resources, weeds also act as an alternate host for insect-pests and diseases. Besides the individual effects of weeds and insects on crops, these two types of pests and their management practices can interact and impact crop production.

The rice mealybug *Brevennia rehi* (Lindinger) (Hemiptera: Pseudococcidae) has been reported as a serious pest in many Asian countries[13], America[14] and Australia[15]. In Asian countries, the pest is widely spread in Bangladesh[16], China[17], India[18–20], Malaysia[21], Sri Lanka[22], Pakistan[21,23] and Myanmar[24]. In India, although rice mealybug has shown its presence in Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Maharastra, Odisha, Tamil Nadu and West Bengal[25], it has not been considered as a major pest of rice because of its restricted distribution and sporadic occurrence. It is mainly confined to upland and rainfed environments. However, the pest may become a potential threat to rice in future due to its global distribution and changing climatic scenario[26]. The insect (both nymph and adult) directly sucks plant sap and causes leaf curling and wilting of the crop plants, and indirectly spreads diseases[27]. High density of the insect (>100 mealybugs/hill) causes severe damage to plants[26]. Moisture stress, well-drained soils and the presence of grassy weeds that harbour this insect favour the population build-up of rice mealybug. Grassy weeds such as *Echinochloa colona*, *Echinochloa crus-galli*, *Cynodon dactylon*, *Leptochloa chinensis*, *Panicum repense*, *Paspalum scorbiculatum* and *Eleusine* spp. and sedges, viz. *Cyperus rotundus* and *Cyperus iria*, were reported as alternate hosts of rice mealybug in Nepal and India[26,28]. In USA, rice mealybug has been reported as tuttle mealybug-infesting *C. dactylon*[29]. The pest was first reported in Iraq on *C. dactylon*[30].

A study was initiated in 2009 at the ICAR Research Complex for Eastern Region (RCER), Patna (25°30′N lat. 85°15′E long. and 52 m amsl), Bihar, India, to examine the long-term effect of CA practices on productivity, soil health and pest dynamics in popular rice-based production systems in irrigated ecologies of the MIGP. The treatments included four scenarios, viz. conventional till (CT) rice–wheat–summer fallow system (S1), CT rice–NT wheat–NT greengram (S2-partial CA), NT rice–NT wheat–NT greengram (S3-full CA), and NT rice–NT mustard–NT summer maize (S4-full CA). CT rice was established by transplanting 21-day-old rice seedlings under puddle conditions, and wheat was sown after repeated tilling (4–5 times) of soil. Under NT conditions, crops were sown directly using NT seed-cum-fertilizer drill in the anchored crop residues without tilling the land. Around 30% residues of each crop (except greengram) were left anchored on the soil surface after crop harvest (except in S1, where crops were harvested from the ground level). In case of greengram, after removing mature pods, 100% crop residue was knocked down in the field as surface mulch by spraying non-selective herbicide (paraquat) in S3 and S4; however, in

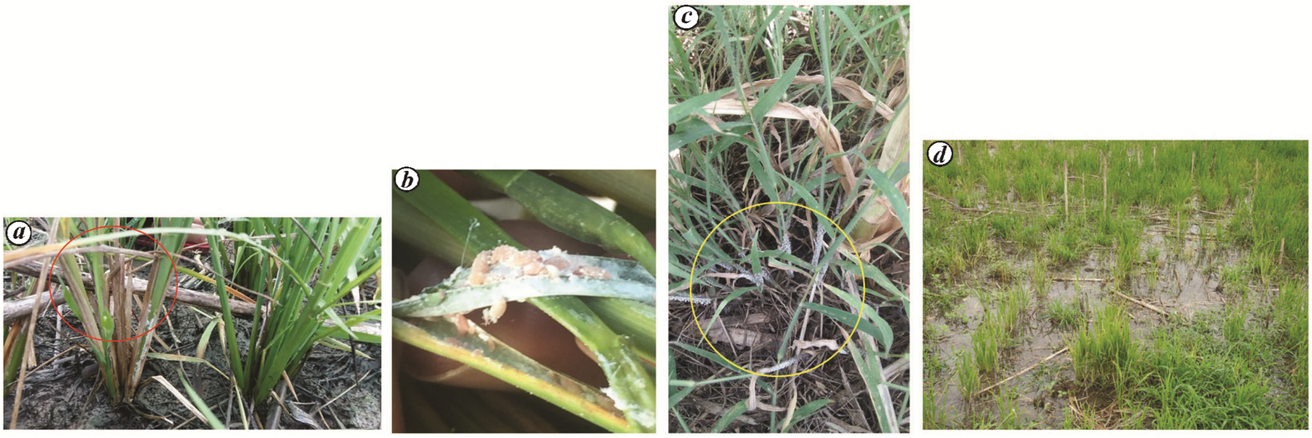

Figure 1. ***a***, Mealybug-infested rice tillers. ***b***, Severe population of mealybugs in rice leaf sheath. ***c***, Appearance of white waxy masses on grassy weeds with previous crop residues as alternate hosts of rice mealybug. ***d***, Rice field severely damaged due to mealybug infestation.

Table 1. Grain yield of rice (t/ha) over time under different scenarios

Scenario	2010	2011	2012	2013	2014	2015	2016	2017	2018
S1	4.4^{b}	6.5^{b}	6.5^{b}	5.5^{b}	6.7^{b}	5.3^{b}	5.4^{a}	6.1^{a}	7.0^{a}
S2	4.8^{b}	6.8^{ab}	6.6^{b}	6.4^{a}	6.6^{b}	6.0^{a}	5.7^{a}	6.6^{a}	7.2^{a}
S3	5.4^{ab}	7.2^{ab}	7.2^{a}	4.8^{c}*	7.5^{a}	5.6^{b}	4.4^{b}	4.6^{b}	6.6^{b}
S4	6.2^{a}	7.4^{a}	7.4^{a}	4.6^{c}*	6.2^{c}	6.2^{a}	2.5^{c}	3.6^{c}	5.2^{c}

*Yield loss due to crop lodging in No-till Direct-seeded rice (S3 and S4) owing to heavy rainfall.
For each year, means within a column do not differ significantly ($P = 0.05$) if followed by the same letter.

Table 2. Total grassy weed population under different scenarios

Scenario	Total population of grassy weed (no./m^2)		
	2016	2017	2018
S1	2.5^{c}	1.0^{c}	2.5^{c}
S2	3.0^{c}	1.5^{c}	3.0^{c}
S3	45.21^{b}	38.51^{b}	10.67^{b}
S4	102.3^{a}	89.5^{a}	26.34^{a}

For each year, means within a column do not differ significantly ($P = 0.05$) if followed by the same letter.

S2, the greengram plants were ploughed down in the soil before puddling. Recommended package of practices for management of insects, diseases and weeds was followed for each crop.

In the present study, no pest incidence was observed till 2015 under any scenario. However, during *kharif* 2016, severe outbreak of rice mealybug was noticed in NTDSR in S4 and S3. This was the first incidence of rice mealybug infestation in rice under CA system. The pest infestation and damaging effect was more severe in S4 than in S3 (Table 1). The infested number of tillers/hill (Figure 1 *a*) varied from 6.24% to 9.38% in S3 and from 22.56% to 28.38% in S4 during *kharif* 2016. The total number of mealybugs/hill was 20–28 in S3 and 72–84 in S4 (Figure 1 *b*). It was observed that the population density of grassy weeds, namely *E. colona*, *L. chinensis*, *Digitaria sanguinalis*, *C. dactylon* and *Brachiaria ramosa* was higher in CA system (S3 and S4) compared to S1 and S2 (Table 2). Grassy weeds like *E. colona*, *L. chinensis* and *D. sanguinalis* were dominant in S3, whereas *D. sanguinalis*, *B. ramosa* and *C. dactylon* were dominant in S4. *E. colona* was also observed in S1 and S2, but very less in number. Annual grasses and perennial weeds are favoured by low soil disturbance in the CA system[31,32]. These grassy weeds have been reported as alternate hosts for rice mealybug[26,28–30], and provide alternate shelter to the mealybugs to survive and multiply in the off-seasons (Figure 1 *c*). It is possible that rice mealybugs survived during winter and summer seasons on grassy weeds as well as on 30% crop residues/stubbles[33], which were left in S3 and S4. Grassy weeds, viz. *E. colona*, *C. dactylon*, *B. ramosa*, *D. sanguinalis*, etc. also grow well during summer season, and atrazine (the recommended herbicide for weed control in maize) has poor efficacy against these grassy weeds. Crops of the poaceae family, viz. rice, sugarcane and sorghum are the preferred host for this pest[34]. As maize also belongs to the Poaceae family, it is possible that the mealybugs present on previous crop residues/stubbles and grassy weeds might have used summer maize and grassy weeds as alternate host, and multiplied rapidly in large numbers in succeeding rice crop in S4, resulting in severe damage. From 2010 till 2015, rice grain yields in S3 and S4 were higher or on par with S1 and S2. However, from 2016 onwards, the yields were reduced in full CA system (Table 1). The effect was more pronounced in S4 than in S3. The maximum yield reduction was observed during 2016 due to severe outbreak of the pest (Figure 1 *d*). Although control measures were taken thereafter, the declining trend in grain yield continued till 2018.

Under changing global climate scenario, CA in rice-based cropping systems is being promoted to mitigate the adverse effects of climate change on crop productivity. This report of rice mealybug at an epidemic level in long-term NT direct-seeded rice in India indicates that it could become a potential threat to the crop under CA system in future. Therefore, appropriate strategies for its management, including control of grassy weeds in crops and field bunds, crop residue management and crop rotation need to be developed for the success of rice-based CA systems.

Conflict of interest: Authors declare that there is no conflict of interest.

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