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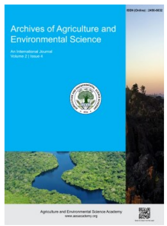

ORIGINAL RESEARCH ARTICLE

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Comparative analysis of knowledge and management practices of insect pests of maize among IPM adopters and non-adopters in Sindhupalchok, Nepal

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ABSTRACT

Integrated pest management (IPM) is a decision-based approach that involves optimizing the pest population below the economic threshold by the coordinated use of multiple tactics in an economically and environmentally sound manner. The adoption of IPM in farming practices prevents long-term pest damage by combining biological control, modification of cultural practices, habitual manipulation, and use of resistant varieties. In Nepal, mostly in hilly regions, haphazard chemical pesticide application has inevitable effects on human health, the environment, and the ecosystem. The haphazard chemical pesticide application in Sindhupalchok, Nepal originated mostly due to a knowledge gap in the identification of the stages of the lifecycle of pests, and the distinction between beneficial and harmful insects. To compare the effectiveness of management practices between IPM adopters and non-adopters this study was framed for six months in Sangachokgadi municipality, Sindhupalchok, Nepal. The knowledge gap among the maize growers in Sindhupalchok was assessed using both primary and secondary data collection methods. For primary data collection a comprehensive and structured questionnaire, face-to-face interview, phone call interview, and Key Informant Interview was conducted. Similarly, secondary data was collected from various articles and publications from Maize Zone, the Ministry of Agriculture and Livestock Development (MoALD), Nepal Agriculture Research Council (NARC), and National Maize Research Program (NMRP). The collected data were then analyzed (descriptive statistics, chi-square test, and indexing) by using computer software packages i.e., Statistical Package for Social Science (SPSS) version 26, and Microsoft Excel 2010. The analyzed data revealed maize growers adopting IPM practices for crop management are known to have significantly better knowledge of the life cycle of pests, were able to distinguish between beneficial and harmful insects, and had knowledge of appropriate fertilizer doses. Further, the findings revealed IPM adopters had better knowledge of chemical pesticide handling which could minimize the chemical hazards among the farmers.

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INTRODUCTION

The second most important cereal crop, after rice, in Nepal is maize (Kandel, 2021). It is grown in all three distinct agroecological zones, namely, the Terai (below 900masl), the Hills (900-1800 masl), and the Mountains (above 1800 masl) (Khanal *et al.*, 2018). The proportionate increase in the area of maize production was highest in the mountains followed by hills and terai, while the proportionate increase in production and productivity was highest in the terai region followed by hills and mountains (Pandey *et al.*, 2009). Maize cultivation is a way of life for most farmers in the hills of Nepal. It is the staple cereal and is an important component of food security. There is an increasing demand for maize for food, feed, and seed. Among the total maize produced, the highest share of production was utilized as feed, followed by food for human consumption, and the least as a seed source in the hills of Nepal (Timsina *et al*., 2016). This increasing demand for maize has made maize production a huge potential for smallholder farmers. Although Maize is recognized as an industrial crop worldwide, it has limited production in Nepal despite its huge potential. The cultivated area of maize is 956,447 ha in Nepal with a production of 2,713,635 mt. with a productivity of 2.84 mt/ha (MoALD, 2019). It is the major crop of hills in Nepal which accounts for 72% of maize production in the country (Paudyal *et al*., 2001). Sindhupalchok district, a hilly district, accounts for 24,687 ha. area of maize cultivation and a total production of 69,445 mt. with a productivity of 2.81 mt/ha (MoALD, 2019). This productivity is far below of attainable yield; the recommended productivity of Sindhupalchok is 5.52mt/ha (MoALD, 2019). The gap in the attainable yield and actual yield is the result of biotic and non-biotic factors. Lack of proper irrigation, ecological uncertainties, diseases, insect pest, weeds, and environmental stresses are the main causes of the decrease in production (Paudyal *et al*., 2001).

Among all other factors, insect pests are one of the major yield-reducing factors in maize production. The global crop production loss due to insect pests is estimated to be between 20 to 40% annually (FAO & CIMMYT, 2018). Likewise, it is estimated that Nepal losses around 20-35% of its crop due to pests (Ghimire, 2005). In the case of maize crops, yield losses of 24-75% have been reported by the attack of insect pests (Sharma & Gautam, 1970). The loss of grain in storage, due to insect pests, is also significant (Bhandari *et al*., 2015). Thus, insect pests cause a significant loss in maize. The major insect pest occurring in the maize field may be classified as; those that attack the vegetative stage such as white grub (*Phyllophaga rugosa*, Melsheimer), fall armyworm (*Spodoptera frugiperda*, J.E. Smith), cutworms (*Agrotis ipsilon*, Hufnagel); those that attack the reproductive stage such as maize stem borer (*Chilo partellus*, Swinhoe), leafhoppers (*Dalbulus maidis*, Del. & W.), ear cutting caterpillar (*Mythimna separate*, Walker), fall armyworm (*Spodoptera frugiperda*, J.E. Smith); those that attack the ripening stage like the stink bugs (*Halyomorpha halys*, Stål); and those that inhabit the soil such as white grub (*P. rugosa*, Melsheimer) etc. (HIRAI, 1991). Another major problem is the lack of awareness among the farmers about the management practices for the major insect pests (Bhandari *et al*., 2019). Chemical pesticides are the common culture of pest and diseases management in many crops in Nepal. But, Integrated Pest Management (IPM) strategies are also popular in many farming communities in Nepal. Integrated Pest Management (IPM) is a decision-based approach that involves optimizing the pest population below the economic threshold by the coordinated use of multiple tactics in an economically and environmentally sound manner (Ehler, 2006). The adoption of IPM in farming practice prevents a long-term pest damage by combining biological control, modification of cultural practices, habitual manipulation, and use of resistant varieties (Flint, 2012). In the present context, haphazard chemical pesticide application is causing an inevitable deleterious effect on human health, environment, and the ecosystem (Ansari *et al*., 2014). However, in IPM practice, pesticide application is done only after monitoring and indication of their needs based on the established guidelines or principles resulting a minimum risks on human health, beneficial non-target insects, and the environment (Peshin & Zhang, 2014). The increasing demand for maize has a huge potential for smallholder farmers in the country; however, insect pests and diseases are important crop-limiting factors in maize cultivation. The fall armyworm (*S. frugiperda*, J.E. Smith), an invasive pest of maize and other crops is regarded as the most devastating pest of maize followed by cutworm (*A. ipsilon*, Hufnagel), stem borer (*Chilo partellus*, Swinhoe), white grub (*P. rugosa*, Melsheimer), and maize aphid (*Rhopalosiphum maidis*, Fitch). Integrated Pest Management (IPM) training has been adopted to reduce pesticide consumption in maize fields as well as encourage farmers toward agro-ecological pest management in many districts of Nepal including Sindhupalchok. Training evaluation provides feedback for upcoming training that can help to draw a future roadmap and way forward of training. The problem of insect pests in maize cultivation is soaring which is why farmers are attracted to short-term and rapid solutions from chemical insecticides (Moss, 2019; Wilson & Tisdell, 2001). The haphazard and excessive use of chemicals against insect pests has a deleterious effect on human health, non-target insects, and the environment (Ansari *et al*., 2014; Haddi *et al*., 2020; Peshin & Zhang, 2014). As the study suggests, the adoption of IPM augments the knowledge of identification of insect pests, and their biological cycle among the farmers; this allows farmers to monitor and keep records of the insect pests and provides a guiding principle to control the pest population below the economic threshold level. Further, IPM practice significantly increases the use of physical control methods (traps, and mulching), cultural control methods (trap cropping, crop rotation, split dose of fertilizer application, and use of well rotten FYM), biological control methods (identification and preservation of beneficial insects), and chemical control methods, as a last resort, as per the recommended dose and use of safe pesticides (plant-based, green tagged, or yellow tagged). Further, the study suggests that the adoption of IPM practice allows farmers to significantly identify the beneficial insects and conserve them against the chemical pesticide effects. Thus, in conclusion, the adoption of IPM allows maize growers to integrate different approaches to pest control causing less perilous effects on human health, the ecosystem, and the environment. Hence, IPM training can change the knowledge, attitude, and practices towards chemical pesticides and promote agro-ecological management of insect pests, preserving the beneficial insects, in maize crop. Such practices should promote in farming communities to reduce the over-reliance of chemical pesticides and improve human health, environment, and biodiversity. Thus, to assess the usefulness of IPM adoption in minimizing the deleterious effects of chemical pesticides and to observe the impact on knowledge, attitude, and practice (KAP) of insect pest management, a study was done among the maize growers of Sindhupalchok district.

MATERIALS AND METHODS

Study area, sample size, and data collection technique

The data used in this study is based on the farm-level study conducted in the Program Implementation Unit (PIU), Maize Zone, Sindhupalchok, Bagmati Province of Nepal. The maize zone is located at Chautara Sangagadichok Municipality. It lies at 27.27^0N to 28.13^0N latitude and 85.27^0 E to 86.06^0 E longitude and is located at the height of 747 m to 7085 m. It covers 1.73% of the total area of Nepal and has an area of 2542 sq. km. The annual rainfall is about 2,500 mm and temperatures vary from 7.5^0C to 32^0 C. Sindhupalchok is an agricultural-based district as 77% of the active population is involved in agriculture. Raosoft (2004) was used to determine the sample population from among the 500 registered farmers of PIU, Sindhupalchok, at a 90% level of confidence and a 10% margin of error. A total of 60 households were surveyed from February to April 2021 for the study. Thirty IPM adopter farmers and thirty IPM non-adopter farmers were selected by simple random sampling from the list of maize growers in the PIU. Both primary and secondary data were taken for the study. Using a comprehensive and structured questionnaire, the primary data was collected from simple randomly selected samples. Face-to-face interview, as well as phone call interview, was conducted due to the covid19 restrictions. In addition, key informants' interviews were taken as a major source of primary data. Similarly, secondary data was collected from various newsletters, brochures, annual reports, newspaper articles, and booklets from Maize Zone, Ministry of Agriculture and Livestock Development (MoALD), Nepal Agriculture Research Council (NARC), and National Maize Research Program (NMRP).

Data analysis

The information collected from the field was first coded and entered in the database. Data entry and analysis (descriptive statistics, chi-square test, and indexing) were done by using computer software packages like the Statistical Package for Social Science (SPSS) version 26, and Microsoft Excel 2010.

Indexing: Farmer's perception of the major problem of insect pests was presented in the five-point scaling technique (Midega *et al.*, 2016). The scale values of 1, 0.8, 0.6, 0.4, and 0.2 were used for most severe, severe, moderate, mild, and most-mild problems, respectively.

Mathematically,

$I = \sum(Sifi/N)$

Where,

I = Index value (0 < I > 1)

Si = Scale value

fi = Frequency of respondents

N= Total number of respondents

Comparison of knowledge and management practice of insect pests of maize between IPM adopter farmers and IPM non-adopter farmers: The Chi-square test was used to compare the knowledge and management practice among the two groups.

RESULTS AND DISCUSSION

Descriptive statistics of socio-demographic characteristics of maize farmers

The descriptive statistics of surveyed farmers are presented in Tables 1. In the study, there were 35 (58.3%) male participants and 25 (41.7%) female participants. Most of the farmers belonged to the age group of 33 to 60 and 38.3% of the farmers have got a secondary level of education. Most of them utilize maize for home consumption followed by feeding cattle. The average family size was 6 members, the average maize cultivation area was 9.6 Ropani, and the average maize production was 17.67 Muri in the study area.

Table 1. Socio-demographic categorical variables of the maize farmers.

Categorical variables	Frequency	Percentage
Gender of respondent		
Male	35	58.3
Female	25	41.7
Age of respondent		
Less than 33	16	26.7
33-60	39	65.0
More than 60	5	8.3
Education of respondent		
Illiterate	13	21.7
Primary (1-6)	15	25.0
Secondary (7-12)	23	38.3
Graduate	9	15.0
Purpose of maize cultivation		
Home consumption	26	43.3
Sell/Market	14	23.3
Seed production	3	5.0
Cattle feed	17	28.3

Table 2. Indexing and ranking of major insect pests of maize.

Problems	Most severe	Highly severe	Moderately severe	Less severe	Least severe	Weight	Index	Rank
	1	0.8	0.6	0.4	0.2			
Fall armyworm	37	3	9	9	1	48.6	0.81	1
Cutworm	12	24	17	7	0	44.2	0.74	2
Stem borer	6	30	22	2	0	44	0.73	3
White grub	5	3	12	27	14	26.2	0.44	4
Maize aphid	0	6	0	15	45	15	0.25	5

Table 3. Knowledge of identification of stages of pests between IPM adopters and non-adopter farmers.

Identification	IPM adopters (n=30)	Non-adopters (n=30)	Total (N=60)	Chi^2 value	p-value
Egg	8 (26.7)	4 (13.3)	12 (20.0)	1.667	0.1967056
Larva	19 (63.3)	9 (30.0)	28 (46.7)	6.696***	0.0096606
Pupa	6 (20.0)	3 (10.0)	9 (15.0)	1.176	0.2780757
Adult	22 (73.3)	12 (40.0)	34 (56.7)	6.787***	0.0091807

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Major insect pests of maize

From key informant interviews and pre-testing questionnaires, five field insects of maize were identified as major insect pests of maize in the survey area. When the survey was conducted among the farmers, fall armyworm (S. frugiperda, J.E. Smith) was ranked as the most severe insect pest of maize with an index value of 0.81, followed by the cutworm (A. ipsilon, Hufnagel) with an index value of 0.74. Stem borer (C. partellus, Swinhoe), white grub (P. rugosa, Melsheimer), and maize aphid (Rhopalosiphum maidis, Fitch) were ranked third, fourth, and fifth respectively with an index value of 0.73, 0.44, and 0.25 respectively.

Comparative analysis of knowledge and management practices between IPM adopters and non-adopter farmers

Knowledge of identification

This study focused on the analysis of knowledge between IPM adopters and non-adopter farmers regarding the identification of insect pests based on their appearance in different stages: egg, larva, pupa, and adult. The result shown in Table 3 shows that IPM adopter farmers can significantly identify the insect pests based on their appearance in larval and adult stages, unlike the non-adopters. Identification of insect pests in the field allows taking action before the pests become a serious problem (Schoelitsz *et al*., 2019). Rather than simply eliminating the pest, identification of insect pests allows farmers to thrive in an environment that is unfavorable for the rapid soar in insect population. The development of effective pest control strategies is reliant on the identification of pests and their status (Gogi *et al*., 2017). For instance, the identification of larval stages of fall armyworm is found to be crucial for the management of the pest (Bista *et al*., 2020). The study report suggests that IPM adopters are more likely to identify the pests in their larval and adult stages and thus seek timely management measures for effective control of the pest population.

Knowledge of other aspects related to pest management

The maize growing farmers of the study area were surveyed to understand their knowledge of different aspects related to maize cultivation. It was found that IPM adopter farmers had highly significant knowledge of beneficial insects, fertilizer doses, and monitoring and recordkeeping in comparison to IPM non-adopter farmers (Table 4). Likewise, IPM adopter farmers had significant knowledge of the life cycle of pests, and chemical pesticide handling. Similar results were found in a study in Uganda. IPM knowledge enhanced the idea about the life cycle of the pest, identification of beneficial insects in the field (Erbaugh *et al*., 2010), and better handling of chemical pesticides (Erbaugh *et al*., 2001). The practice of IPM for the management of insect pests significantly decreases the pest population and the consumption of chemical pesticides (Morse & Buhler, 1997). The knowledge of monitoring and recordkeeping is another important aspect of the successful management of insect pests of the crop. This allows farmers to keep track of the number, types, and damages of the pests. The economic threshold of insects is extensively useful to make insect control decisions (Czapar *et al*., 1995). The study revealed that IPM adopter farmers have highly significant knowledge of monitoring and recordkeeping compared to IPM non-adopter farmers.

Management practices of insect pests of maize

The study revealed that the IPM adopter farmers significantly use traps and mulching compared to non-adopters (Table 5). However, a significant difference in the use of soil solarization and fencing/barrier was not found between the two groups. A similar observation was found among tea growers in Bangladesh; the adoption of IPM enhanced the use of traps, more precisely, the light traps and pheromone traps (Mamun & Ahmed, 2011). Likewise, the use of mulching is found to be significantly effective in the management of *Drosophila suzukii* in the fall-bearing raspberry (McIntosh *et al*., 2022). Physical control includes the application of mechanical or manual methods to kill the pests or cause disturbance in their behavior. Some of the methods of physical management applied in IPM are the use of traps (like light traps, pheromone traps, sticky traps, and so forth), mulching, soil solarization, and fencing/barriers (Flint, 2012). Cultural control includes the farming practices that play roles in maintaining the pest population below the threshold level (Tang *et al*., 2005). The practice of trap cropping,

Table 4. Knowledge of other aspects related to pest management between IPM adopters and non-adopter farmers.

Knowledge	IPM adopters (n=30)	Non-adopters (n=30)	Total (N=60)	Chi^2 value	p-value
Life cycle of pests	17 (56.7)	9 (30.0)	26 (43.3)	4.344**	0.0371419
Beneficial insects	20 (66.7)	9 (30.0)	29 (48.3)	8.076***	0.0044864
Fertilizer doses	21 (70.0)	11 (36.7)	32 (53.3)	6.696***	0.0096606
Chemical pesticide handling	19 (63.3)	10 (33.3)	29 (48.3)	5.406**	0.0200676
monitoring and Recordkeeping	19 (63.3)	8 (26.7)	27 (45.0)	8.148***	0.0043105
Stages of plant growth	25 (83.3)	19 (63.3)	44 (73.3)	3.068*	0.0798387

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

Table 5. Management practice of insect pests between IPM adopters and non-adopter farmers.

Management	IPM adopters (n=30)	Non-adopters (n=30)	Total (N=60)	Chi^2 value	p-value
Physical					
Traps (light, pheromone, sticky)	21 (70.0)	10 (33.3)	31 (51.7)	8.076***	0.0044864
Mulching	21 (70.0)	11 (36.7)	32 (53.3)	6.696***	0.0096606
Soil solarization	19 (63.3)	13 (43.3)	32 (53.3)	2.411	0.1205074
Fencing/Barrier	28 (93.3)	25 (83.3)	53 (88.3)	1.456	0.9795778
Cultural					
Trap crop	24 (80.0)	14 (46.7)	38 (63.3)	7.177***	0.0073843
Crop rotation	22 (73.3)	13 (43.3)	35 (58.3)	5.554**	0.0184355
Weeding	27 (90.0)	25 (83.3)	52 (86.7)	0.577	0.4475209
Fertilizer application in split dose	23 (76.7)	12 (40.0)	35 (58.3)	8.297***	0.0039707
Use of well rotten FYM	22 (73.3)	14 (46.7)	36 (60.0)	4.444**	0.035015
Change in irrigation pattern	18 (60.0)	15 (50.0)	33 (55.0)	0.606	0.4362749
Biological					
Identification & Preservation of Beneficial insects	19 (63.3)	8 (26.7)	27 (45.0)	8.148***	0.0043105
Introduction of Beneficial insects	9 (30.0)	7 (23.3)	16 (26.7)	0.341	0.5593049
Chemical					
Application in recommended dose	22 (73.3)	12 (40.0)	34 (56.7)	6.787***	0.0091807
Use of safe pesticides (Plant-based or Green tag or Yellow tag)	23 (76.7)	13 (43.3)	36 (60.0)	6.944***	0.008408

Note: *significant at 10% level, **significant at 5% level, ***significant at 1% level.

crop rotation, change in irrigation pattern (Katan, 2000), weeding, fertilizer application in split dose (Ramzan *et al.*, 2007), and use of well rotten FYM (Kapse *et al.*, 2018) are some of the cultural control measures. In the study, IPM adopter farmers had significantly used cultural management practices like trap cropping, crop rotation, fertilizer application in split doses, and the use of well rotten FYM for the management of insect pests in a maize field (Table 5). However, weeding and change in irrigation patterns were not found to have significant differences among IPM adopter farmers and IPM non-adopter farmers. The structure, function, and relationship of plant community with soil in crop rotation contributes to the long-term control of insect, weed, and disease incidence; so, crop rotation is becoming a more popular approach for maintaining sustainable crop production (Shah *et al.*, 2021). Similarly, trap crop attracts insects and pests for oviposition and feeding, as well as, serve as a sink for insects or the pathogens they vector (Shelton & Badenes-Perez, 2005). Likewise, in an experiment in Gujrat, India, it was found that the susceptibility and incidence of insect pests increased with an increase in the fertilizer dose, and it was suggested to split the doses of fertilizer to decrease the pest incidence (Ramzan *et al.*, 2007). In another study in Maharashtra, India, it was reported that the majority of the respondent (71.67%) adopted the use of well rotten FYM as a means to control soil-born insects (Kapse *et al.*, 2018).

Biological control of insect pests in IPM includes the introduction and conservation of natural enemies of exotic origin to control the pests population below the economic threshold level (Kenis *et al.*, 2017). This natural enemy includes parasitoids, predators, and occasionally pathogens and vertebrates (Kenis *et al.*, 2017). The study revealed that the IPM adopter farmers significantly identified and preserved the beneficial insects as compared to non-adopter farmers (Table 6). But, the introduction of beneficial insects or other biological entities did not find significant difference between the two groups. In Nepal, biological control has a high scope and the mass production and introduction of parasitoids like *Trichogramma chilonis* is being practiced on a trial basis; however, its commercialization among farmers is still a challenge (Gautam, 2008). The farmers who are aware of the identification and benefit of beneficial insects (example: ladybird beetle, some bees, and wasps) conserve them and protect them from pesticide effects but, their introduction for insect pests control is found only on a few commercial farms (Shields *et al.*, 2018). In IPM chemical insecticides and pesticides are used only when needed and in combination with other approaches. In this practice, the use of chemical pesticides is done in a way that minimizes the deleterious effects of chemicals on human health, non-target organisms, and the environment (Peshin & Zhang, 2014). As shown in Table 5, the study reflects that the IPM adopter farmers have significant knowledge of the application of chemical insecticides and pesticides in the recommended dose, and the use of safe pesticides (plant-based pesticides or chemical pesticides labeled with green or yellow tags) in comparison to IPM non-adopter farmers. Extensive and prolonged exposure to hazardous chemical insecticides and pesticides can lead to cardiopulmonary disorders, neurological and hematological symptoms, skin diseases, and serious health hazards (Pingali *et al*., 1995). Thus, the use of safe insecticides in recommended doses can prevent health hazards in humans (Peshin & Zhang, 2014). Likewise, the use of the right dose and selective pesticides promote a sustainable and benign ecosystem, thus, minimizing the deleterious effect on the non-target organism, and the environment (Ndakidemi *et al*., 2016)

Conclusion

In conclusion, the study underscores the critical importance of Integrated Pest Management (IPM) in mitigating the challenges posed by insect pests in maize cultivation within Nepal's Sindhupalchok district. The findings reveal that IPM adopter farmers exhibit significantly heightened levels of knowledge and implementation of various pest management strategies compared to non-adopters. These strategies encompass a spectrum of approaches, including physical control methods such as traps and mulching, cultural practices like crop rotation and fertilizer application in split doses, and judicious use of chemical pesticides. Importantly, IPM adopters demonstrate a keen awareness of the necessity to conserve beneficial insects and minimize reliance on chemical interventions, thereby promoting environmentally sustainable pest management practices. By integrating diverse pest control tactics in a holistic and environmentally friendly manner, IPM offers a multifaceted approach to address the challenges of insect pests while simultaneously enhancing crop productivity and minimizing adverse impacts on human health and the ecosystem. Moreover, IPM empowers farmers with the knowledge and skills necessary to make informed decisions regarding pest management, enabling them to adopt practices that are tailored to their specific agro-ecological contexts. Moving forward, the promotion and adoption of IPM practices among farming communities in Sindhupalchok and beyond hold significant promise for achieving sustainable agricultural development. Emphasizing IPM training and extension services can serve as a catalyst for widespread adoption of environmentally friendly pest management practices, thus contributing to food security, biodiversity conservation, and the resilience of agricultural systems to pest-related challenges. By fostering a shift towards more sustainable and ecologically sound farming practices, IPM has the potential to play a pivotal role in ensuring the long-term viability and resilience of maize cultivation in Nepal and similar agricultural contexts worldwide.

Authors contribution

Conceptualization: BB; Methodology: BB and APS; Software and validation: BB and ST; Formal analysis and investigation: BB; Resources: BB; Data curation: BB; Writing- original draft preparation: BB; Writing-review and editing: BB, ST, APS, DG, and AK; Supervision: APS and ST. All authors have read and agreed to the publication version of the manuscript.

Conflicts of interest: The authors declare no conflict of interest.

Ethical approval: Not applicable.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

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