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Successes of Integrated Pest Management in Sorghum Production: A Review

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***Abstract**: Most of the world's crop yield has stayed constant during the previous few decades, especially in developing nations. While the average actual yields of 0.5 to 1.5 tonnes per hectare are below the potential yields of crops like sorghum, maize, rice, wheat, and groundnuts. Losses brought on by insect pests and other illnesses are mostly to blame for the enormous discrepancy between potential and actual yields. There are more than a thousand different types of insects. On farms and in storage, 150 species wreak havoc on sorghum harvests. Aphids, wireworms, armyworms, midges, and stem borers are a few of the insect pests that have been identified for sorghum. Therefore, host plant resistant varieties, natural plant products, biopesticides, and precision agronomic approaches are the main elements of integrated pest management. However, the sampled publications from around the world have demonstrated the benefits of IPM for the cultivation of sorghum (e.g. Rabi in India, the USA and East Africa).*

Keywords— Agriculture, Insects, Weeds, Crops, Yield, Agriculture, Food

1. INTRODUCTION

Agriculture takes up the majority of the planet's surface area, and the type of space used differs in ways that are important for the technologies, inputs, and outputs that may be produced there. Because of regional variations in temperature and natural resource endowments, agricultural systems are frequently site-specific(Uusitalo et al., 2019). In terms of farm size, products produced, technology used, inputs used, farm incomes, and other economic consequences, farms and farming are extremely diverse(Clinton et al., 2018).

The variety of crops grown around the world includes maize, potatoes, wheat, rice, groundnuts, soy beans, beans, Bambara nuts, jute, oats, and many others that are essential(Hinz et al., 2020). The population of the rural and peri-urban globe faces difficulties notwithstanding achievements and agricultural crop production serving as a backbone. As a result, farmers around the world have claimed that input costs, weeds, and pests are all impediments to agricultural productivity(Pellegrini & Fernández, 2018).

Chemicals have been used by farmers for a long time to manage plant and insect pests in their agricultural crops(Okosun et al., 2021). The majority of weed killers and pesticides have been harmful to the environment, including the people handling them while spraying or applying them. Therefore, it is clear that chemical management measures greatly increase crop failure during various cropping seasons(De Roest et al., 2018). Crop failure is typically brought on by chemical control reductions from the prior cropping year that may not be favourable to the current crop, particularly for insecticide. In addition to chemical residues and contaminated field soil, pests including aphids, armyworms, and cutworms provide farmers significant economic challenges due to their destructiveness(Costa et al., 2019). Farmers have only used chemical sprays to get rid of pests, which have been shown to be bad for the environment. When compared to conventional methods of controlling weeds and insect pests on farmed fields, researchers came up with an economical strategy that is also environmentally benign(Munyaneza & Bizimungu, 2022).

The public's growing concern over the possible negative effects of chemical pesticides on human health, the environment, and biodiversity served as the impetus for the poll(Torretta et al., 2018;Ali et al., 2021). Though they cannot be completely eliminated, the severity of these negative externalities can be reduced by creating, disseminating, and promoting sustainable bio-intensive ways(Torretta et al., 2018). The latter led to the development, promotion, and global implementation of Integrated Pest Management (IPM) programs.

What is IPM? IPM is a comprehensive and powerful strategy to crop and animal protection that integrates a number of tactics (e.g. cultural, physical, mechanical, biological, botanical and chemical). IPM has changed considerably over the years,(Grasswitz, 2019) shifting its emphasis from damage border, economic injury, to economic threshold(Bueno et al., 2021). Currently, the majority of stakeholders rely on economic threshold levels (ETL)(Nawaz et al., 2019) and frequently use chemical pesticides as soon as a pest infestation occurs (e.g. the Government of India had advocated for the need based and judicious application of chemicals in cultivated farmlands). Due to issues with pest resurgence, pesticide resistance, and sustainability, the strategy is likely (Ali et al., 2021)to have negative consequences on agro-ecosystems and raise the cost of agricultural production(Prasad, 2022).

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Why Integrated Pest Management? Given the extensive ecological imbalances brought on by highly intensive agricultural systems, the necessity for an environmentally sustainable agricultural practise is imperative(Hagstrum & Flinn, 2018). Integrated Pest Management (IPM) has advanced from an ETL-based approach to an Agro-ecological system analysis-based approach in order to address the negative effects of chemical pesticides and weedicides on agro-ecological systems. As a result, (Dyck et al., 2021)a new paradigm called Ecological Engineering for Pest and Weed Management is making progress as a means of advancing Bio intense Integrated Pest Management(Dara, 2019). Ecological Engineering for Pest Management, on the other hand, makes use of cultural practises to alter habitats and improve biological control(Deguine et al., 2021).

What is Sorghum crop? Sorghum [*Sorghum bicolor* (L.) Moench; Family: Poaceae] is a genus of grasses with about 30 species, one of which is raised for grain and many of which are used as fodder plants, either cultivated or as part of pasture(Ananda et al., 2020). Around the world, the crop is grown in warm areas. Sorghum is a crop that originated in Africa and is now widely produced and consumed as food (e.g. alcoholic beverages, biofuels, fodder for dairy animals, grain and in sorghum syrup or "sorghum molasses"). The majority of sorghum types are heat- and drought-tolerant, making them a crucial crop in desert areas(Teferra & Awika, 2019).

One of the primary foods for the underprivileged and rural populations of emerging nations is sorghum grain(Videgain-Marco et al., 2020). A cane-like grass with huge grain clusters that are branching, sorghum can reach heights of six metres(Shoko & Belete, 2017). The individual grains have a modest diameter of 3–4 mm. Depending on the cultivar, they range in colour from pale yellow to reddish brown to dark brown. Few sorghum varieties are permanent plants, while the majority are annual crops. The majority of the weedy sorghum in these crops is non-rhizomatous, and the nodes of the culms are either glabrous or briefly tomentose(Teferra & Awika, 2019).

The inflorescence's branches alternate, and they are primarily constricted. As a result, wild types feature loose inflorescences with spreading branches and a distinctive ring of long hairs at the nodes. The inflorescence's branches are whorled. Sorghum leaves turn over occasionally and resemble maize leaves considerably more(Ananda et al., 2020). More than two broad leaves may be present on a single plant. Two varieties of blooms are carried in the flower head; one has no stalk and both male and female components, while the other often has a stalk and is male. However, a variety of biotic limitations, including weeds and insect pests, have a significant impact on the yield of sorghum(Kahsay et al., 2018).

More than 150 species of insects are pests of sorghum from emergence through the late grain filling stage, according to Du et al. (2020) The quality of the grain used in brewing and milling is impacted by insect pest feeding(Okosun et al., 2021). In West Africa, losses from stem borers infestation alone range from 11 to 49 percent, in East Africa, between 15 and 88 percent, and in Southern Africa, between 50 and 60 percent, according to Overbelt (2001) research. Therefore, across Africa and Asia researchers have estimated insects causes losses over $1.1 billion in losses each year.

Guo et al. (2011) calculated that sorghum yearly production losses in Northern and Southern China ranged from 50% to 70% as a result of insect pest feeding damage. While in India, agricultural losses from insect infestations were roughly 35%, costing $580 million. In the United States, between 0.5 and 4.0 percent of the annual sorghum yield was thought to be lost each year to pest damage caused by insects, however in Southern Florida in 2013, researchers have alluded losses from insect infestation reached 90 percent for various sorghum varieties. Additionally, the sugarcane aphid caused damage to sorghum in Texas, United States, and caused farmers to lose $31.60 million in revenue between 2014 and 2015, a report by Zapata and colleagues in 2016.
Therefore, this study synthesizes on the previous research work on the biological significant sorghum pests in various countries, present management techniques, and potential sorghum insect pest control options.

Among other dozen pests that are responsible for reduction in yield of sorghum and important, ones include:

a) Sorghum shootfly (*Atherigona varia soccata* Rondani).
b) Stem borer (*Chilo partellus* Swinhoe).
c) Sugarcane aphid [*Melanaphis sachari* (Zehntner)].
d) Shoot bug (*Peregrinus maidis* Ashmead).
e) Grain midge (*Stenodiplosis sorghicola* Coquillett).

Therefore, the following findings about how each insect pest impacts the yield of sorghum were obtained from an experimental study that was carried out in India:
Head bug (*Calocoris angustatus* Lethierry) which varies in time and space and is reflected in low grain yields with avoidable losses ranging from 12 to 83% (Prem Kishore, 1987).

Shoot fly damage results in yield losses up to 90 per cent (Jotwani and Srivastava, 1970).
The sorghum aphid (M. sacchari) tends to feed on the underside of older leaves, which causes premature leaf drying, non-filling of grains, and a decline in the quality of crop. Across the globe there has been a drop in the yield of sorghum. Recent studies have reported a 77% drop in sorghum grain yield, highlighting the severity of aphid damage among other pests. However, Aphid infestation reduced grain and fodder yield by 11.74 to 26.13 percent and

9.83 to 31.43 percent, respectively, with an overall average loss of 16.09 and 14.99 percent.

Shoot-bug has become a severe pest in some areas of Andhra Pradesh, Karnataka, and Tamil Nadu as a result of the introduction of hybrids that mature at different times. In India, losses from severe infection at the boot stage can reach 41 percent because the upper leaves are twisted and panicles are prevented from emerging. The shoot bug poses a significant obstacle to the development of Rabi sorghum by inflicting both direct and indirect damage by sucking up sap and spreading the viral illness sorghum stripe.

Beneficial Insects to sorghum crop; in sorghum, a variety of useful arthropod species are frequently found. They will assist in reducing troublesome bug species. To prevent beneficials from being mistaken for pests, proper identification is crucial. The species of beneficial insects found in grain sorghum are typically the same as those seen in other field crops. Lady beetles, syrphid or hover fly larvae, big-eyed bugs, damsel bugs, minute pirate bugs, lacewings, ground beetles, spiders, and various parasitic wasps and flies are examples of common helpful arthropods.

Birds; several bird species, such as blackbirds, can invade grain sorghum throughout the hard dough to maturity period where they perch on panicles and consume seed. Birds eat whole seeds but also break them up by taking bite-sized bits and leaving half of the seed on the panicle. Because of the seed's clean break and exposed white endosperm, this injury is simple to identify. Birds will also urinate while feeding, and the upper leaves and panicles will be covered in their feathers and faeces.
Sorghum crops are classified as non-commercial in most underdeveloped nations, including Ethiopia, and farmers hardly ever use synthetic pesticides on their crops. Thus, efforts have been made to evaluate various IPM components' effectiveness in developing nations' rain-fed environments. The productivity of these crops is being increased in every way possible by implementing contemporary agricultural techniques, such as the utilisation of high yielding cultivars.

1.2. Significance of study

This review is crucial for the cultivation and conservativative management of the sorghum crop among smallholder farmers in Sub-Saharan African nations and other parts of the globe. According to the sampled literature, sorghum is one of the least farmed crops and is quite vulnerable to insect pests. The success of Integrated Pest Management on sorghum crops around the world makes this article relevant to promote and crucial for smallholder farmers.

2.1. SUCCESSES OF IPM IN SORGHUM PRODUCTION

Over the 20th century, IPM has developed to address the negative effects of synthetic chemical pesticides on the environment, which eventually damage the interests of the farmers. The economic threshold level (ETL) served as the foundation for several decades, but in contemporary IPM (FAO, 2002), farmers are given more attention so they can base their decisions on a wider variety of field observations. The environment, which consists of both physical (such as soil, rain, daylight hours, wind, etc.) and biological variables, influences the state of health of a plant (i.e. pests, diseases and weeds). All of these elements may influence the equilibrium between herbivorous insects and their natural adversaries. The management of pests can benefit greatly from an understanding of the complex interconnections that exist in an ecosystem. View the table below.

Table 1 depicts Economic Threshold Levels of sorghum insect pests.

Pest	***Infestation level***
Shoot fly	10% dead hearts
Stem borer	10% plant with damage symptoms
Midge	5 midge/ear-head
Ear-head caterpillar	2 larvae/ear-head
White grub	1 grub/m2 area
Grain mold	20% incidence of physiological maturity
Nematodes	1-2 nematodes/g of soil
Rodents	15 live burrows/ha.

The field experiment was carried out in Rabi, 2015–2016, at the Regional Agricultural Research Station, Vijayapur, Karnataka, India, to evaluate the Integrated Pest Management (IPM) components for the management of insect pests in rabi sorghum. Integrated pest management techniques that were used in all treatments include the following:

A. Chemical Control Measures

The three most crucial components of chemical control measures falling under the purview of IPM are need-based, wise, and safe application of pesticides. It entails the development of IPM skills to protect the environment through optimal crop health, monitoring, and conservation of the natural biocontrol population before opting to apply chemical pesticides as a last resort.Spraying of the Endosulfan at 2ml/ at 7-14 days after sowing minimize shoot fly(Karabhantanal, 2018).

1. Application of Malathion 10D, Phorate 3G at 8-12 kg/ha at 20 and 35 days after emergence effectively control the borer.

2. Application of Carbaryl 50 SP at 20 kg/ha or Endosulfan at 472g /ha prior to flowering openings can effectively check the midge infestation.
3. Spraying of Mancozeb 0.3% or captain 0.3% from flowering to earhead stage at 10days interval can control grain mold.

B. Weed management practices

1. Summer ploughing for destroying stubbles and perennial weeds.
2. Timely sowing of crop to minimize crop weed competition.
3. Proper spacing to facilitate inter-weeding operation.
4. Two manual weeding 2-3 & 6 weeks after sowing.

C. Rodent management practices

1. Bund trimming to minimize rodent harbourage
2. Demolish the existing rodent burrows.
3. Use of indigenous traps.
4. Apply 2.5% (1:40) zinc phosphide bait preceded by one day prebaiting followed by bromodiolone (0.005%).

D. Cultural practices

1. Deep summer ploughing followed by following helps in exposing resting stages of pests.
2. Trimming of bounds, uprooting, and destruction of crop residues.
3. Selection of healthy seeds of less susceptible varieties (e.g. CSV-10, SPV 839, ICSV-745 among others) against midge, downy mildew and charcoal rot.
4. Early planting minimize the chances of shoot fly, midge and ear head bug damage.
5. Planting date in Kharif 7-10 days onset of monsoon and in Rabi end of September to 1st week of October is deal to escape the shoot fly.
6. Maintain plant spacing 45 cm X 15 cm.
7. Use balanced fertilizer at 80 kg nitrogen, 40 kg K2O.
8. Removal of grassy types and Johnson grass is beneficial to reduce the midge population.

E. Mechanical practices

1. Destroy thrashed sorghum heads before the onset of monsoon for borer and midge control.
2. Use light trap and pheromone traps at five (5) traps/ha.
3. Removal of dead hearts.

F. Biological control practices

1. Conservation
   - 1.1. Conserve biocontrol agents like Tricogramma, Apanteles, Eriborus, Carabids, ladybird beetles, Chrysopa, spiders, etc.
2. Augmentation
   - 2.1. Seed treatment with Trichoderma viridi, T. harzianum at 4g/kg against soil borne diseases.
   - 2.2. Release of Trichogramma chilonis at 75, 000 adults/ha/week.

G. Botanical pesticides

1. Use neem cake at 200 kg/ha for control of Nematode(Karabhantanal, 2018).

In some parts of the world, like East Africa, the push-pull strategy is employed to reduce stem borers' damage to sorghum by planting a semi-attractive non-crop plant (trap plant) whose semiochemicals attract the pest and a non-host trap crop whose semiochemicals repel the pest from the planting of sorghum this was reported by Khan in 2000 and Tekle in 2016. Therefore, in the practice the leguminous intercrops in the push-pull system help to increase soil fertility and retain moisture while companion crops provide feed for farm animals (Buntin, n.d.).

In Western Ethiopia, an integrated strategy of sound farming practices and the application of botanical and chemical pesticides during the storage of sorghum grain was successful in lowering seed damage and the % weight loss of stored grains for various storage pests. However, chemical and oil ash treatments, either individually or in combination, were successful in minimizing crop loss in Eritrea's stored sorghum (Haile, 2006). In Burkina Faso, novel approaches to the management of storage pests include the use of biological control, bio-pesticides, and hermetic storage.

CONCLUSION

The first step in integrated pest management for sorghum is choosing resistant types that are well suited to the local growing environment. This tactic is supplemented with other cultural techniques such crop rotation, shifting the best time to plant, using trap crops, growing allelopathic or non-host plants, destroying crop residue (e.g., burning decreases), and maintaining clean fields. Additionally, the potential for commercializing the use of botanical pesticides against insect pests on farms in Africa, America, and Asia by small-scale farmers should be further investigated. For low-income farmers, it will be cost-effective to develop sorghum cultivars with many types of resistance against important insect pests.

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