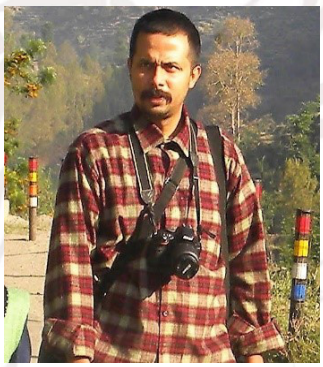

The hand of demon behind Bee Eclipse

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Let us sway a bit from our fleshy reality.
Imagine yourself in the southern districts of rural Bengal, in the fields of bitter gourd on a bright warm, and humid summer morning. The climbing vine with dark green, deeply lobed leaves is teeming with bright yellow, dioecious flowers. You may be wandering to catch a glimpse of butterflies or bees hovering over the greeny cover with yellow blobs on their legs or abdomen.
But wait!
……..
You are confronted with a new murmur!

What is a bunch of small kids doing amid the vines, seems like playing and touching the flowers with their soft nimble fingers! This act of touch-playing kept you wondering what exactly happening in the early morning.

Then you spring out and might turn to someone who looks a bit knowledgeable and experienced. And what you figure out is quite mind-boggling!

Small kids are nothing but acting as winged creatures and pollinating bitter gourd flowers. Pollinators are in great decline for years in the region so sensed local farmers. With their soft fingers, kids facilitate the connection between anther and stigma, so as to enhance the transfer of pollens. As a result, fruit formation spurts and also the yield. Bees are the major actor in bitter gourd pollination. These vivacious kids are actually doing the job of bees or other pollinating fauna, hand-pollinating the yellow flowers of bitter gourd. It ensures the fruit formation in the absence of bees, and butterflies

The decline of pollinators has become a very common phenomenon in agriculture, and so has the perception around it. Farmers and people associated with agriculture already are well-informed through their own experiences. If you move to the next village and collide with any other cross-pollinating crop you might find the same story spoken to you, and another band of kids joyfully flower-touching and achieving the integral step of pollination and accelerating the subsequent fruit formation. So, farmers have become aware of the fact quite sometimes

back and they are employing their own remedial measures to circumvent this critical bottleneck in agriculture.

Similar observations by farmers of Odisha, Punjab, Kerala, Maharashtra, and Tripura echo the impending danger stemming from the shrinkage of the honeybee population. Even, beekeepers from various states have recorded anecdotal accounts of the decline. However, a validation of preliminary information seemed difficult for scientists because of a paucity of pre-existing data to make a comparison.

Only a few sporadic studies have attempted to chart out the decimation of bee populations but their geographical coverage is limited. A study in Odisha by Smith et al (2017) collated and validated the traditional agroecological knowledge of the farmers to understand an environmental challenge pertaining to pollinator decline in India. It uncovered that the yields of vegetables have decreased in many areas of Orissa as reported by farmers. In addition, the abundance of key insect pollinators, particularly *Apis cerana* or eastern honey bee, *Amegilla* sp. or digger bees, and *Xylocopa* sp or Carpenter bees, have declined sharply in the last 10–25 years. Among five key types, four, e.g., *Apis cerana, Apis florea, Amegilla spp,* and *Xylocopa spp*, underwent a steep decline of nearly 70-90 percent, exception of *Apis dorsata*. Notably, the farmers have related the pollinator decline to the quantity and number of pesticides used. They also suggested that fewer pesticides, larger natural habitat spaces, and the introduction of hives could support pollinators. A similar study assessed the link between the use of agrochemicals and wild bee populations in 127 agricultural plots around Bangalore, Southern India (Steinhübel et al. 2022). The results highlighted the role of agricultural intensification in a decrease of the abundance and richness of wild bees. They suggested the regulation of agrochemical use, and crop rotation to diminish the harmful effects of intensive pest management. Earlier, a compilation of research studies reported the endangered status of giant honeybees in India and other parts of Asia (Oldroyd and Wongsiri 2009). On a similar note, a couple of other studies show that agricultural land with lower pesticide use had higher bee diversity.

Thus, putting all the pieces of the fragmented images that emerged from various scientific studies, the picture becomes quite complete: the decline of bees is an imminent crisis that has been hatching for quite some time now and the absence of these omnipresent creatures from the agricultural ecosystems has been evident, even in the general perception of commoners.

Whom to blame?

Although with a wild guess, we can surmise that the process of decline was already set in motion, things have not gone this far several decades back. Or has it? In a large-scale study, researchers working in disjunct geographic locations discovered that the intensified production systems used to apply heavy dosages of pesticides are to be blamed for this degradation (Dicks et al. 2021).

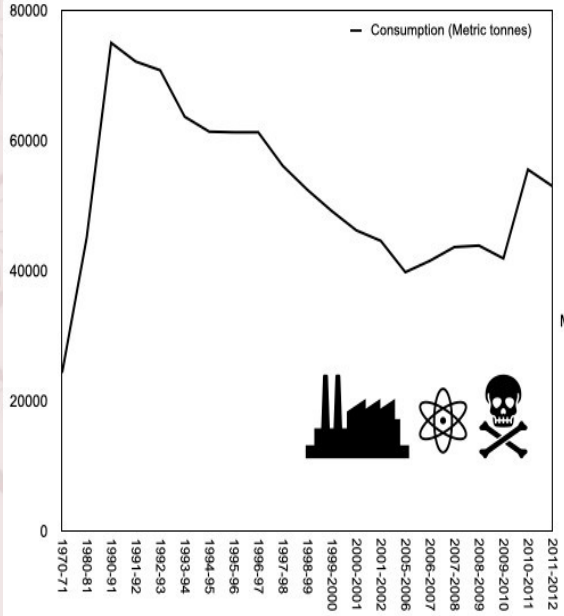
We know that with the Green Revolution or a little earlier, the saga of industrial farming commenced in India and so began the unregulated application of agrochemicals on the crops. We calculated it or not, or we documented the gradual process of decline or not, the culture

of agrochemical use, its scale and magnitude, has built up slowly year after year, decade after decade. Eventually, the heavy doses of agrochemicals on various crops in intensified production systems have taken a huge toll on biodiversity in anthropogenic landscapes and on pollinators as well. Bees have prey to this change in their anthropogenic ecosystems and elsewhere. The traditional knowledge of the farmers and analyses by the scientists unequivocally echo this concern.

Industrial farming: Rise of agrochemical empire

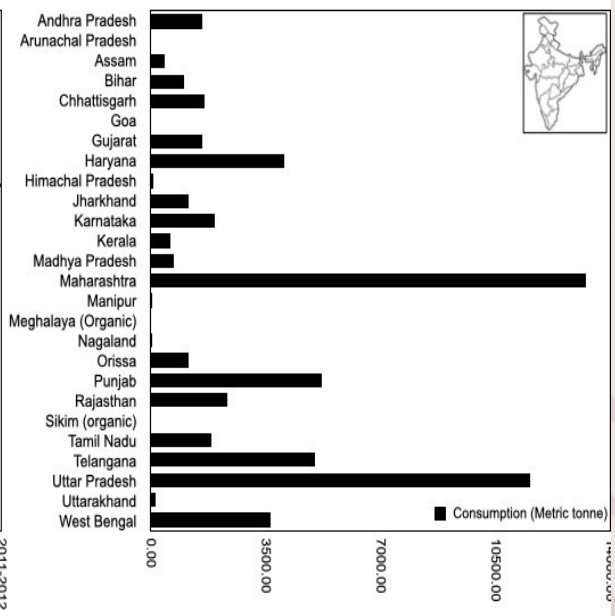
Now every story has a beginning, and so has this story.
I have here a brief outline reconstructed from scattered evidence. The narrative of gradual development of chemical agriculture that was stirred up with the Green Revolution…..
Industrial agriculture fueled the rise of the great agrochemical empire among other things (figure - 1a-b). Prior to it, a suite of near-locally available materials, cow dung or other animal excrement, mustard cake, bone meal, animal or plant wastes, and human excrement, were utilized in the field. The GR promoted a scientific narrative of high yield that required nitrogenous fertilizers for plant growth in the first place for its bushy, semi-dwarf cultivars (Khush 2001). Monoculture of cereal crops (primarily rice and wheat) coupled with genetic homogenization owing to crop improvement programs opened the gate for higher pest infestation than earlier. Eventually, it unleashed the application of numerous chemicals that have been applied to a plethora of crops growing on Indian soil or elsewhere, some received more treatment than others for their economic importance, rice and cotton are two crops receiving major pesticide treatment.

Figure 1- a: Year-wise Consumption of Pesticides (1970-2012)



Source: Source : Indian Agriculture in Brief; Indiastat.com

Figure 1-b: State-wise Consumption of Pesticides (2020-21)



Source: States/UTs Zonal Conferences on Inputs (Plant Protection) for Rabi & Kharif Seasons.

Over the years, the consumption skyrocketed and newer generation chemicals crowded out the older ones. As a result, the soil was degraded, water bodies were contaminated, our food was laden with chemical residue at an alarming rate, and farmers were on the treadmill which only allowed more and more resource consumption. Bees, an integral part of ecosystems, were subjected to chemical toxicity to various degrees. Scientists say pesticides are the single most important factor underlying bee decline at an alarming rate. Greatly alarmed by the decline, there has been a surge of studies to investigate the nitty-gritty of the decline and its causal relation to industrial agriculture aka pesticides. It has been found that bees are often chronically exposed to cocktails of pesticides throughout their development and afterward, though the effects of this are yet to be clearly unraveled.

But how do these chemicals act?

Of many agrochemicals, the chemicals to defend against pest attacks are generally detrimental to the non-pest or natural enemy biota. The whole suite of chemicals, insecticides, herbicides, or fungicides, poses life-threatening risks to the bees through multiple mechanisms. Most insecticides are generally sprayed over the crop canopy, whereas herbicides and fungicides are routinely sprayed directly on the soil before the planting of crops. Therefore, droplets and dust generated from the applications, in all these cases, can easily fall on the foraging bees since wind can carry the droplets and dust a few hundred meters away from the application site. A single droplet of insecticide, mostly containing concentrated doses of the chemicals, can kill a bee (Greig-Smith et al. 1994). So, one can easily imagine the scene when thousands of such droplets float in the air on a sunny morning with flowers in full bloom and bees happily foraging in the field.

The threats posed by systemic insecticides act in a different manner because they are usually applied as seed coatings. Systemic insecticides are taken up by the growing crop plants. The residues are present in all parts of the treated plants including the flowers, pollen, and nectar the areas of bees' interest (Bonmatin et al. 2015). The damage does not preclude non-crop weeds, hedges, and bushes that grow nearby are also affected. Generally, the exposure of bees to pesticides happens through the ingestion of residues in pollen and nectar of crops or weeds. Although bees forage everywhere in search of the most suitable flowers with copious pollen and nectar, some crops are more attractive than others. For example, the yellow flowers of mustard, sunflowers, and many weeds or ornamentals are more attractive to bees than other flowers like brinjal, potato, or tomato. Pesticides can also reach through other routes, eg., residues in soil are eventually accumulated in the water of streams, tanks, ponds, or non-perennial water bodies. Bumblebees, honey bees, and wild bees are used to drink from puddles, ponds, and streams, and contaminated water reaches their digestive system and enters into the physiological and biochemical processes (Samson-Robert et al. 2014). In addition, residues in pollen and nectar are also carried to the bee colonies and remain in the beebread and honey, fed to the larvae and the queen, which are affected in similar ways as the forager bees (figure - 2).

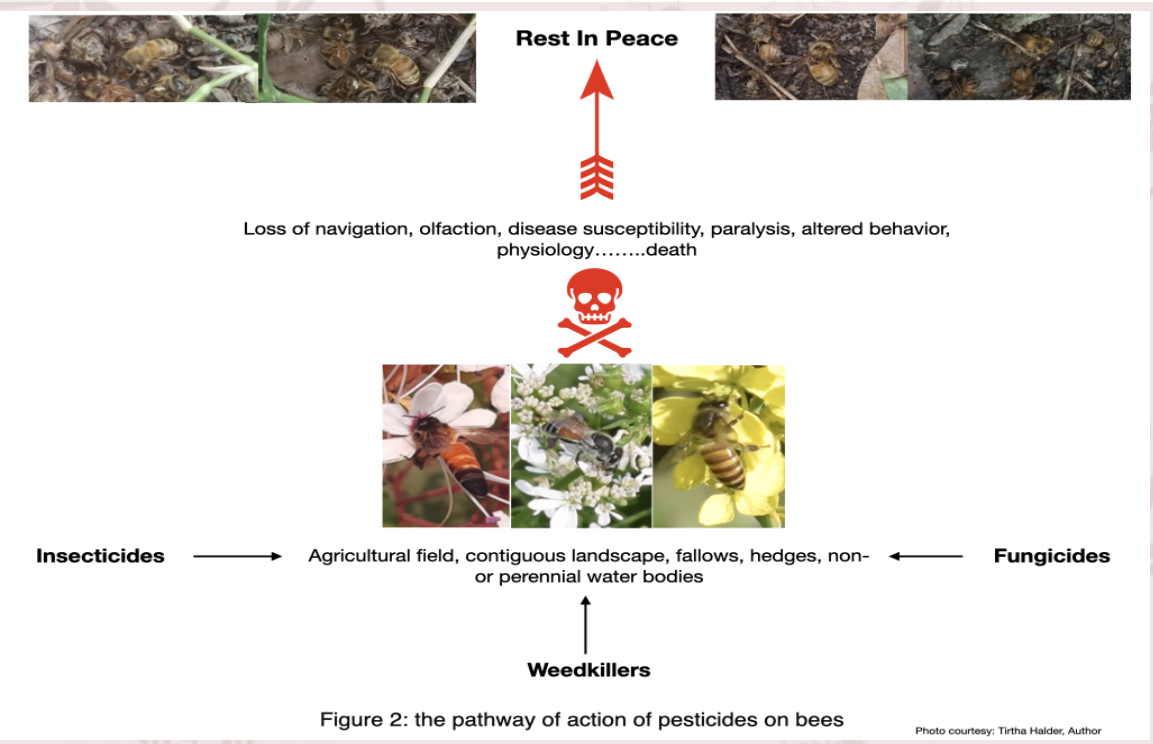


Figure 2: the pathway of action of pesticides on bees

Interestingly, more than hundred fifty different pesticides of differing toxicity potential have been detected in honey bee colonies. Sanchez-Bayo and Goka (2016) went one step forward. They predicted that three Neonicotinoids (Thiamethoxam, Imidacloprid, and Clothianidin), and the Organophosphates (Phosmet and Chlorpyrifos) are the greatest threat to honey bees globally analyzing the data on toxicity, frequency in hives, and the concentrations. Importantly, pesticides often do not work in isolation but often join with other factors to exacerbate the problem, for example, exposure to pesticides can damage both detoxification and immune responses in bees. Thus, longer and sustained exposure turns bees more susceptible to parasites further endangering their health and survival.

Recently, there has been a lot of furor over the use of Neonicotinoids pesticides which have already been infamously tagged as one of the most harmful of all. However, the first information report goes a decade back, when multiple studies published pinned down the cause of the decline. They highlighted the role of Neonicotinoids that can be lethal for bees' functioning. For years, Neonicotinoid insecticides have successfully controlled pests in various crops. They claimed to have zero phytotoxicity and are mostly compatible with all relevant crops. Its use is increasing over the years owing to its better safety profile compared to other commonly used pesticides like Organophosphates, Organochlorides, and Pyrethroids. Neonicotinoids are currently the most widely used group of insecticides globally holding one-fourth of the agrochemical market. The better toxicological profile is attributed to more selectivity for insects compared to mammals. However, they may not only affect pest insects but also non-target organisms such as pollinators. A lot of findings have been published and many opinions have been voiced. To date, the research on the hazardous effect of Neonicotinoids has been confined to the environmental Neonicotinoid residue levels in crops and pollinators and sub-lethal effects to pollinator populations. Since they are systemic

insecticides, absorbed into the plants, and can be present in pollen and nectar. Many laboratory studies described the lethal and sublethal effects of Neonicotinoids on the foraging behavior and learning and memory abilities of bees. Woodcock et al. (2017) reported that honeybee and wild bee exposure to Neonicotinoid pesticides reduces their ability to establish new populations. Besides, research on the effects of Neonicotinoids on pollinators is primarily restricted to honey bees but other pollinators are similarly affected. In India, Neonicotinoid pesticides were first registered for use in the mid-1990s and became a commonly used agrochemical group. However, with the overall decline in pollinators owing to Neonicotinoids or other pesticides, their impact on pollinators and food security has become a cause of concern.

Ironically, we are on the ride of a roller-coaster over which we do not have any control over its speed, let alone stop. How can we stop using chemicals which have become so integral to our agricultural practice? One can go to a village and asks a farmer, whether he will be confident of doing farming without synthetic chemicals, he is least likely to be confident. Pesticides reached the core of our culture of agriculture and it is ingrained now.

In the end…

Up to this, all of the painted pictures look so negative, depressing, and grim with pessimism. But, certainly, there are rays of hope that instigate us to be optimistic, at least slightly!
Recently, a selective ban on a handful of toxic pesticides has been ordered. But, the actual number is far less than what has been proposed based on their toxicity (Mahapatra 2023). On the other hand, India's consumption of various biopesticides is rising steadily. Sustainable agriculture, organic farming, regenerative agriculture, and natural farming building on the basic principles of agroecology are thriving gradually in different geographies with various degrees of success. They largely divorce the use of harmful chemicals and instead urge to use of farmyard manure, organic decoction (*jiwamrit*), or environment-friendly alternatives and various agricultural management techniques to bypass harmful chemicals. One of the states which has made it in faster strides is Andhra Pradesh. The Govt of Andhra Pradesh initiated the program, A.P Zero budget natural farming, in 2016 which is performing well. Taking cues from this, a few other states are moving forward. But, much remains to be done in order to nurture healthy bee-friendly agroecosystems that would ensure our future access to safe and secure food.

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