Natural farming: Is it safe to march ahead?

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Summary

Due to the increasing global population, advancement in farming techniques to meet the global food demand is the need of the hour. Conventional farming techniques have increased the yield over the past few decades, but those techniques also have adverse effects on natural resources. In this scenario, many other alternatives have emerged as a solution, natural farming being one among them. The presented article delivers crucial information regarding the targeted farming technique *i.e.*, natural farming. Multiple scientifically-proven natural techniques and ecological approaches are discussed for different aspects of farming. In addition, criticisms related to Natural Farming are illustrated along with a basic introduction to zero budget natural farming (ZBNF). Furthermore, the article describes multiple proven technologies for weed, pest and disease management approaches through natural practices. Lastly, the article gives recommendations on implementing and introducing natural farming to the farming community.

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INTRODUCTION

India's food production increased tremendously after the green revolution (GR) era and became self-reliant. Days of the ship to mouth are long gone. Using GR technologies like intensive cropping system, use of high-yielding varieties of seeds, chemical fertilizers, irrigation, and agricultural mechanization, the country is now food self-sufficient and even exporting many agricultural commodities.[44, 13, 10] However, at the same time, aggressive farm-sector intensification led to multiple drawbacks and significant environmental adversities: soil compaction in the plough layer, land degradation, aquifer eutrophication, greenhouse gas (GHG) emissions, biodiversity losses, the emergence of herbicide-resistant weeds, and shift in weed flora, declining groundwater table, burning of crop residues and environmental pollution, decreasing factor productivity, multi-nutrient deficiencies, burgeoning production costs, and declining farm profits. In addition to sub-standard food quality and these problems deteriorating human and livestock health.[44, 38, 39, 9, 8, 10, 13]

Considering the current scenario, there is a need to consider alternative farming systems for greener and sustainable food production without compromising the nation's long-term food production and nutritional security. Wallenstein[67] advocated restoring soils and feeding microbes to rejuvenate the soil. This can be achieved by adding and recycling organic material to the soil, minimizing tillage, and excluding the usage of synthetic fertilizer and chemical growth regulators. Among the existing approaches, natural farming (NF) and organic farming (OF) are being contemplated as pathways to improve soil life, ensure optimum conditions for crop development and overcome multifarious problems. This article aims to systematically and comprehensively synthesize the available information on these practices, emphasizing NF.

The NF is an ecological, chemical-free, diversified farming approach that integrates crops, trees, and livestock, allowing functional biodiversity.[45, 57] The NF philosophy is

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based on the principle of working in harmony with nature and natural cycles for producing safer and healthy food while maintaining the health of soil, humans, and livestock. NF was introduced by Japanese farmer and philosopher Masanobu Fukuoka (1913–2008), and described in detail in his famous book "The One-Straw Revolution". This approach of farming is also known as "the Fukuoka method", "the natural way of farming," or "do nothing farming," etc. Natural farming refers not to the lack of effort but to exclude the manufacturers' inputs and equipment.[30]

Likewise, OF is also an approach to chemical-free agriculture that avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators, genetically modified organisms, and livestock food additives.[65] Both NF and OF target chemical-free food production with safer and greener food, but fundamentally both are different approaches. The resemblances and dissimilarities in the two systems are hereunder:

Resemblances between organic farming and natural farming

Both NF and OF exclude the use of agricultural chemicals and primarily consider them as poison for agriculture. The two practices disfavor the application of chemical fertilizers, fungicides, or pesticides on plants and other farm practices/activities. Both approaches advocate for the use of local varieties and landraces of field crops, vegetables, and other crops. The OF and NF promote non-chemical methods and farm-made pesticides to manage pests, diseases, and weeds below threshold levels.

Dissimilarities between organic farming and natural farming

In OF, various organic manures like compost, vermicompost, and farmyard manure, etc., are applied for soil fertility management instead of synthetic fertilizers. Under NF, neither chemical fertilizers nor organic manures are used on the soil or plants. Conventional farming practices like tilling, ploughing, planking, mixing of manures, weed control, etc. are performed under OF, but in NF, no ploughing or tillage, or weeding are undertaken. In OF, manures and composts are incorporated into the soil for their requisite decomposition and this requires more effort and cost. In the NF, organic matter decomposition by earthworms and other microfauna is encouraged on the surface soil layer, steadily adding essential plant nutrients to the soil. Sometimes, OF may have a slight adverse effect on the surroundings as it involves intervening with the natural systems, but NF does not have any impact on the surrounding environment as it relies on local processes and biodiversity only. Further, OF is more about using natural resources optimally to enhance production; hence, this system is still expensive because of the need for bulky organic manures, and it may have an ecological impact on biodiversity. On the contrary, NF is minimalist in operations and human intervention, allowing nature to operate and manage. Therefore, it is an extremely low-cost agricultural approach, totally relying on local biodiversity.

Present status and prospects in the Indian scenario

Globally, the demand for organic products is rising day by day. However, frequent reports of short supplies of organic products are also common, primarily owing to production not matching the rapidly growing demand trends.[25] As per the World of Organic Agriculture, 2018 report, India accounts for merely 2.6% (1.6 m ha) of the global organic cultivation area of 57.8 m ha, but the country is home to nearly one-third of the total global organic products. Though the demand for organic products is growing rapidly, at the same time, organic products usually cost 3-4 times more than chemical-produced products, primarily because of high labor costs, certification expenditure and handling costs, and comparatively lower productivity levels under OF. Furthermore, during the mandatory three-year transition or conversion period from conventional farming to OF, the farmers are required to follow organic practices but not permitted to sell their produce as 'organic,' intimidating poor farmers to adopt OF. The transition process poses a substantial economic risk to the producers, with the typically reduced productivity levels during the conversion period. Contrarily, once the NF is adopted as a non-chemical production system, the farmers can fetch a little premium price for their produce from the first year itself. This is advantageous to compensate for the yield penalties, if any, in the initial years.

As per the projections of Tech. Sci. Research, the global organic food market is estimated to rise at a CAGR of 16.1%, reaching $ 262.85 billion by the end of 2022. In India, the growth projections are around 25% and were expected to be around Rs. 12,000 crores by 2020, as per a joint report by ASSOCHAM and Ernst & Young. India exported organic items worth Rs. 5,151 crores in the year 2018-19, nearly 50% greater than the preceding year. One doctrine contemplates that the global carrying capacity of organic farming is merely 3–4 billion people.[20] It is far below the global population (6.2 billion) and considering the population projections for 2050 (9 billion), it may jeopardize global food security. However, Badgley et al. (2007)[4] believed contrarily and stressed that OF can not only improve crop yields in developing countries but can feed the entire planet. Barbieri et al. (2019)[11] indicated that a 31% decrease in cultivation acreage with the principal cereal grains (rice, wheat, and maize) was compensated by an enhancement in the acreage with temporary fodders crops (+63%), millets (+27%) and pulse crops (+26%) as compared to the traditional practices. Such changes coupled with organic-to-conventional gaps in productivity are estimated to cause a 27% reduction in energy output from farmlands compared to the current production. Further, in analyzing land use change efficiency for changing climate, Searchinger et al. (2018)[59] advocated that foods produced through OF have a bigger climate impact than traditional production, primarily owing to relatively greater land area requirement. This is due to significantly reduced farm yields, as fertilizers are not applied. Hence, a much larger land area is needed to harvest the identical quantity of organic food, leading to more significant carbon emissions. However, from a consumer's viewpoint, organic food products seem to be environment-friendly.

On the other hand, there is a misconception that the OF as an alternative to conventional farming is doing more harm to Indian agriculture than any potential benefit. The primary reason for this is enormous quantities of organic manure requirements under OF, leading to the enhanced cost of production. Further, the availability of large amounts of organic matter is also an issue for large-scale OF adoption. This is why organic products have become elite produce, and only rich people can afford organics at such exorbitant prices. However, there also exists multiple contrasting reports on the benefits of OF. In such a scenario, NF has been advocated by many researchers as a safer and low-cost alternative system of farming with the following advantages:

1. Natural farming is eco-friendly: all the required inputs are made from natural materials. It follows the law of nature while respecting the rights of crops and livestock. This farming system assists in healing the soil damaged by chemicals, herbicides, and machines. Further, long-term NF adoption leads to clean soil and water and ecological recovery.

2. Natural farming respects life: This farming system opposes human exploitation of life. The NF is based on the principle that respecting the nature of life is the best way to realize bountiful harvests and better quality. Diseases are prevented rather than cured with chemicals. Similarly, healthy livestock is reared instead of making animals healthy by administering hormones and antibiotics. The NF crops and orchards also offer greater resilience to climatic extremities and stress events.

3. Natural farming provides high-quality produce: The products obtained through NF have high quality and better taste. It is also claimed that the products of NF have greater nutritional values without chemical residues.

4. Farmers prepare farm inputs: The biggest advantage of NF is that the farmers only prepare the inputs required at the local level. The nutrient sources, soil conditioners, pest controllers, and disease curers are made at the farm itself by the farmers themselves using only locally available natural materials. It is based on the nutritional cycle theory as NF does not involve buying materials from the market and using them on the farm. Only the required quantity of inputs is prepared by the farmers, thereby cutting the cost and improving overall profitability.

Criticisms of Natural Farming

Indian agriculture is socio-economically fragile, with around 85% of its total 146.5 million cultivators being smallholders with a low risk-bearing ability.[26] Nearly 100 million farmers (68.5%) of India operate on an average 0.38-hectare land holding. Likewise, Hazell & Rahman (2014)[36] highlighted that a large section of hungry and poor people across the globe subsists on small landholdings and struggle to survive with low input-low yield technologies on their smaller holdings. Under such a scenario, applying advanced scientific tools, technologies and innovations is the only way out for Indian agriculture. Furthermore, a large section of the scientific fraternity and critics strongly oppose NF, condemning it that it is not scientific evidence-based but promotes a set of certain beliefs system, particularly indigenous cows, and considers it a backward-looking, risky and prejudiced idiom.[60, 58, 27] On NF, the National Academy of Agricultural Sciences (NAAS), a national agricultural science think-tank in India, carried out a brainstorming workshop in New Delhi and strongly voiced that the government should not devote capital and human resources toward promoting zero-budget natural farming (ZBNF), an Indian version of NF. While criticizing ZBNF, the scientific fraternity called it an "unproven" technology with severe risks to national food security and is not expected to bring tangible gains to various stakeholders.[22] Contrarily, a committee under the Chairmanship of Prof. V. Praveen Rao, Vice-Chancellor, PJTSAU, Hyderabad, was appointed by the Indian Council of Agricultural Research (ICAR) to analyze the viability of ZBNF in diverse ecologies of the country.

Zero budget natural farming (ZBNF)

There are several variants of NF, wherein the farmers make need-based local modifications, customizations, and adaptations as per farm typologies and ecologies. But, the stepping-stone for ZBNF or NF in India is the advocacy by the principal proponent of NF, Mr. Subhash Palekar, who has made a few modifications in the technology over time nomenclature. Initially, it was named by him 'Zero Budget Natural Farming, which was later renamed 'Zero Budget Spiritual Farming' (ZBSF), and of late, it has been named 'Subhas Palekar Natural Farming' (SPNF). Mr. Palekar pinpointed the four fundamental ingredients of ZBNF, i.e., *Beejamrit* is a treatment given to the seeds using FYM, urine, and other components to protect the crop from soil and seed-borne diseases; *Jeevamrit* is a natural fertilizer. It acts as a catalyst that enhances the activity of microbes as well as earthworms in the soil. *Acchadana* or mulching is spreading crop straw over the soil surface to reduce evaporation losses and manage the weed population to add organic matter to the soil; and *Whapasa* is a state in which both air, as well as water molecules are present in soil.[50] He carries out training sessions for the stakeholders in various parts of the country and advocates the following:

● Since the inputs are not procured from the outside or market under ZBNF practices, and everything is prepared at the farm only, hence the production cost becomes zero. Therefore, it is named 'Zero Budget'. It is based on the principle that essential plant nutrients are present in the soil, but a larger fraction remains in the fixed or unavailable form. Using microorganisms and microbial cultures, these unavailable elements can be converted into available forms.

● Various Green Revolution technologies such as synthetic fertilizers, herbicides, fungicides, and insecticides have negatively affected soil health, particularly adverse effects on microorganisms in the plant-soil continuum.

● It has been hypothesized that each gram of cow dung contains 300 to 500 crore beneficial microbes. Thus *Jeevamrit*, a farm-made microbial solution, acts as culture. The *Jeevamrit* is a complete and perfect solution for field crop production. The requirements to apply FYM in bulk quantities are not there.

● It hypothesizes that only the dung of indigenous breeds of cows is effective. However, mixing half cow dung and half the dung of bullock or buffalo is permissible in case of non-availability, but not of the Jersey or Holstein breeds of cows at any cost.

● As per ZBNF, only 10 kg/month of cow dung is adequate for each acre of land, and thus it is believed that 30 acres of land can be cultivated with only one indigenous cow.

● Microbes and the unavailable plant nutrients decompose the dried biomass (mulch) on the soil surface are converted into available form. Likely, it also enhances the earthworm population in the topsoil.

● As per Palekar, 2006, the OF is not suitable for resource-poor Indian farmers, as it requires huge quantities of organic manures, making the agriculture non-remunerative. In addition, it is argued that under OF, the earthworm species, *Eisenia foetida*, used in the process of vermicompost preparations, also transforms considerable fractions of heavy metals to their bio-available forms, resulting in their absorption by the plant system leading to their entry into the food chain. Furthermore, the soils contain greater quantities of carbon (C) than the atmosphere and plants. Losing C-rich soil organic matter emits CO2, a greenhouse gas, accelerates global warming. To low down the process of global warming, sequestering the C in soils using cover crops and mulching is an effective strategy. The cover crops take C out of the atmosphere as they grow and funnel it into the soil, in addition to their advantage as soil protectants. Unlike traditional crops and cash crops, where plant harvesting and removal is the set practice, the cover crops are retained on the field to decompose, recycle and contribute to soil formation. The plants and crops are C sources for the soils, whereas the microorganisms control their fate by their food consumption, ensuring that at least a part of the C remains in the soil.[67] It is strongly understood that the ZBNF or NF is founded on the above hypothesis. With diverse interventions under NF, e.g., applying microbes, maintaining soil cover, minimum tillage or soil disturbance, sustainable crop rotations, etc., it assists in the regeneration of soils and ultimately leads to sustainable farming sector growth.

Proven technologies for weed management through natural approaches

Natural, ecological, or non-chemical approaches to managing weeds include planting weed-free seeds, tweaking the planting period, cultivating quick-growing cultivars with competitive abilities, soil solarisation, crop geometry and row orientation adjustments, scientific crop rotations and optimizing seed rate, stale seed-bed method, etc. In addition, resource conservation technologies like laser land-levelling, conservation agriculture and newer crop establishment systems, and scientific water and soil fertility management can also be employed successfully to control weeds in natural farming in various crops and cropping systems. The details are given below:

1. *Clean and weed-free seeds*: Contamination of crop seeds with weed seeds is the foremost weed dispersal mechanism. Several weeds species, like *Phalaris* minor, *Echinocloa* sp., etc., possess phenotypic and chronological mimicry with the host crops, hence get harvested and threshed with host crops, leading to the mixing of weed seeds with crop grains.[43] Most farmers store the harvested output as seed stock for succeeding season sowing. Such practices lead to weed seed contamination. Hence, frequent old seed replacement with high-quality seeds is obligatory to reduce weed infestation. Using clean seeds also minimizes the cost of cultivation. It reduces environmental footprints as huge money is saved by avoiding non-essential operations for weed control, including herbicidal usages, for bountiful yields.

2. *Tweaking planting periods*: Adjusting planting periods and crop sowing at an optimum time provide a competitive advantage to crops over the weed flora leading to higher productivity.[10] Lower infestation of *P. minor* has been reported on early sowing of the wheat crop as temperature during the early season is not favorable for its germination.[15] Likewise, the use of short-duration paddy cultivars like 'Pusa Basmati-1509' allows timely sowing of winter season crops,[61] resulting in lower weed infestation in winter cereals. Therefore, the planting period needs to be standardized as per the intensity and target weed species in a given ecology.[43]

3. *Cultivars with fast growth habits*: After the green revolution, high-yielding dwarf cultivars, particularly in wheat and rice varieties, have occupied a larger share under cultivation. Still, most of the genotypes are poor in weed-suppressing abilities. The cultivars with fast vegetative growth habits quickly cover the ground surface and disfavor the early season weed growth.[18] The varieties with weed-suppression quality have greater specific leaf area with uniformly dispersed leaves and increase biomass and plant height when shaded.[19] In India, Yaduraju and Ahuja (1997)[68] noticed that tall statured wheat variety, C-306, has caused a significant reduction in plant height and dry matter accumulation of Phalaris, as compared with HD-2329 and Kundan cultivars. Similarly, Walia and Singh (2005)[66] reported less infestation of Phalaris in wheat varieties PBW-343, WH-283, PBW-373 and Raj-3765 as compared to varieties WH-157, WH-896 and WH-512. Such findings clearly illustrate that cultivar selection should be location-specific and need-specific depending on weed dynamism for efficient weed management.

4. *Soil solarization*: Weed seed banks in cultivated soils possess dormancy of variable nature resulting in helping weeds to germinate frequently and repeatedly over the years. Even if weeds are controlled fully for many crop seasons, the seed bank having variable dormancy will result in repeated and continuous flushes of weed appearance.[53] Therefore, the soil solarization technique can potentially destroy the weed seed bank, leading to effective weed control. In the soil solarization approach, the entire field is covered with a transparent polythene sheet during the summers,[51] which leads to enhanced soil temperature to a level that proves lethal to underlying weed seeds, harmful insects and pathogenic microorganisms. The soil temperature in solarized plots increases by ~ 12-15°C.[1] The principal cause for this huge escalation in soil temperature is the greenhouse effect and restriction of evaporative cooling under a plastic sheet.[3] Arora and Yaduraju (1998)[2] found a reduction of 85 and 78% in the top 5 cm and 15 cm soil layers, respectively, in the germination of *Avena fatua.* Das and Yaduraju (2008)[24] also observed reduced weed infestation under soil solarization. Considering the above, the soil solarization approach can play a notable role in managing weeds through non-chemical means in the tropics and under sub-tropical ecologies.

5. *Effective crop rotations*: A few weed species are favored by monoculture, and the majority of crop-associated or crop-bound weed species (weeds with identical climatic requirements, growth habits and ontogeny to the host crop) are most aided by the cultivation of the same crop repeatedly over the years.[52] Periodic rotation of crops (with different growth natures, life cycles, and requiring unlike crop husbandry practices) offers many gains over monoculture.[43] Crop rotation disturbs the growth and development of crop-associated weeds by changing the soil microclimate. The weed species which show phenotypic identicalness with crops e.g., the Phalaris and wild oat with wheat, *Echinochloa colonum* and *E. crusgalli* with paddy, etc., are challenging to manage through mechanical means. However, they can easily be detected in other than wheat and rice fields and can be easily

managed through hand weeding. Continuous mono-cropping encourages the enrichment of the weed-seed bank, which can easily be reduced to an optimum and manageable limit by adopting an effective crop rotation.[43] In a similar manner, fodder crops also minimize weed seed production due to their frequent cuttings. Over an extended period, a significant portion of the weed seed bank gets exhausted[17] under rotations involving fodder crops. In addition to weed control, crop rotations involving dissimilar natural crops also improve productivity and farm profits.[9]

6. *Crop geometry and seed rate*: For bountiful harvests, optimum seed rate and row spacing are prerequisites.[6] Enhanced planting density or population increases the competitiveness of crops against weeds, but one should be cognizant of intra-specific competition as well.[43] High planting density reduces growing spaces available for weed plants[7], facilitates early ground cover, and deprives the weeds of sunlight.

7. *Row orientation*: In addition, to planting density, row orientation also affects weed menace levels. Around 18.4–23.4% lower weed density and biomass were observed under criss-cross sowed wheat crop compared to a line-sown crop using 100 kg seed ha-1.[37] Chhokar et al. (2017)[16] found a 2.4% higher yield with reduced weed infestation under criss-cross sowing than conventional line sowing. Criss-cross wheat sowing at 22.5 cm row spacing can manage the weeds equal to the 15 cm row spacing unidirectional sowing, but yield remained 5% greater in the criss-cross way of sowing.[48] Furthermore, crop orientation also affects the quantum of solar radiation intercepted by a crop. Reduced weed biomass and higher yield in east-west oriented wheat were reported as compared to north-south orientation due to greater radiation interception.[14]

8. *Stale seed-bed technique*: To exhaust the weed seed-bank, light irrigation is applied before sowing of the crop to facilitate and stimulate the weed seed germination. Subsequently, such germinated seeds and germinating seedlings can easily be controlled through lighter tillage operations. The crops sown afterward face considerably lesser weed infestations. Although the stale seed-bed technique is an effective weed control strategy, timely planning is a prerequisite. But it is well established that the stale seed-bed method drastically lowers the weed seed-bank in surface soil layers.[40]

In a nutshell, alternative strategies of weed management are obligatory to tackle excessive herbicide uses and overcome emerging problems due to agricultural chemicals. Various ecological/ non-chemical weed management approaches have the potential to overcome the weed menace efficiently. However, considering their limitations, location-specific farming system-based refinements and fine-tunings are required.

Pest and disease management approaches in natural farming

Since much research has not been done on pest and disease management under NF, largely ecologically safer preventive pest and disease management approaches are the only options under NF. NF focuses on maintaining a healthy ecosystem to enable a robust plant system with significant resistance to pest and disease attacks. Broadly, ecosystem management through minor modifications in the cultural methods such as soil quality management and adoption of crop rotation leads to defense against the insect-pests and disease infestations. Further, the adoption of specific ecological curative approaches e.g., the use of parasitoids, predators, plant products and ecological engineering, constitutes the following line of defense against the infestations of diseases and attack insect pests.[31, 32, 33, 34, 35] The details are given below:

1. *Intercropping*: The various intercropping systems are principal strategies among cultural practices to be followed for ecological pest management. It is mainly based on the principle of agroecosystem diversity for pest and disease management, wherein two or more crops are raised simultaneously. In different types of intercropping, strip cropping, two or more crops are grown in alternating strips, is a quite popular intercropping system of pest control.[54] This system of intercropping is based on the hypothesis of "Resource Concentration", where plant-feeding insects are more likely to identify and live in clusters of their host plants which are dense and less diversified.[55] Likewise, Maqsood et al. (2022)[46] analyzed the ecological engineering impacts on the flea beetles, *Phyllotreta striolata* and *Altica himensis* and their natural enemies on the eggplant crop. The findings showed the greatest percent enhancement of natural enemies in the main crop over control (250.52 %), with the highest mean % decline of the target pest population (63.46 %) noticed in Treatment I. The border and intercrop, coupled with the main crop, minimizes pest attack and supports natural enemies by providing food supplements and acting as a refugee.[63] The classic example of this approach is marigold border planting, an improvement in longevity and fecundity of the natural enemies by ensuring nectar

supply. In return, the natural enemies contribute to pollination,[5] resulting in a win-win scenario.

2. *Mixed cropping (Push Pull System)*: In the push-pull intercropping systems, specifically identified companion crop plants are raised in between the main crop, which acts as a push component, and the pull components are plated as borders. The 'push' component in this system repels the insects (using semiochemicals), whereas the 'pull' component, i.e., the trap-crop, attracts the pest species away from the main crop.[21] A thorough chemical-ecology understanding of the plant-insect interactions with different crop species is a prerequisite for an effective push-pull system. Various studies illustrated that some intercrops (silver leaf, *Desmodium uncinatum*, and green leaf, *Desmodium intortum*) resulted in the added advantage of *Striga* weed population decline. For better productivity, such benefits are as substantial as insect management in vegetable crops.[42]

3. *Trap crops*: Trap crops are plants raised to entice insects away from the main crop. While selecting a trap crop, care must be taken that the trap crop species must be more attractive to the insect pests than the main crop and in no case, the pest should migrate from the trap crop to the main crop. Hence, effective utilization of trap crop technology is a challenging strategy that needs a thorough understanding of the food preference behavior of pests.[62] Pest species that are poor or inefficient fliers and need wind assistance to disseminate are ineffective against trap crops (e.g., spider mites, aphids, etc.). The trap crops were designed to be used in traditional insect management systems where agrochemicals may be applied to destroy the trapped pests. Overall, trap crops are significant in insect population control in many food systems.

4. *Cover crops*: The crops with quick growing habits, including green manure crops, living mulches, and catch crops, cover a significant ground proportion in a concise time span. In addition to their soil protection and other advantages, these crops also provide shelter to the advantageous/friendly insect species, e.g., spiders, ground beetles, etc. Further, greater intensive strategies like planting insectary strips of temporary nectar and pollen species like brassicas, buckwheat, clovers, etc. within the crop field itself. The migration of beneficial organisms takes place from the cover crop to the main crop after the end of the flowering period. Nonetheless, when beneficial organisms are required for the main crop, mowing the cover crop facilitates the early migration of beneficial organisms to the main crop.[47] Further, the use of brassicas (rapeseed and mustard, radish, cabbage, canola) is another unique strategy, wherein the brassicas are grown as cover crops which are subsequently buried in the surface soil using a hand plough or soil turning plough, and on the decomposition, various substances released reduces nematode population drastically.[23] Furthermore, Nicholls et al. (2001),[49] showed that mowing of alternate cover crop rows pushes *Anagrus* wasps and various other predators onto the main crop vines. Likewise, the density of nymphs of leaf hopper on vines remained static in the cover-cropped lines before mowing. After one week of mowing, the nymphal population reduced on the vines where mowing of the cover crop was carried out. It was coincided with an enhanced population of *Anagrus* in cover crop rows that were mowed. After two weeks, nymph density reduction was further intense, coupled with an enhanced *Anagrus* population in the crop foliage.

5. *Flower strips*: Tschumi et al. (2016)[64] reported flower strip effects on aphid's natural enemies in potato crops. They found that planting a flower strip of mixed seeds of the annual flowering plants provides an incessant and good magnitude of floral and extra-floral nutrients, which are accessible to vital natural enemies of the aphids. Based on extensive studies, it was found that various flowering species like *Anethum graveolens*, *Camelina sativa*, *Centaurea cyanus Bellis perennis*, *Anthriscus cerefolium*, *Calendula arvensis*, are effective for the purpose. In addition to improved aphid biocontrol, such flower strips also have added advantage of enhanced biodiversity of natural enemies and reduced insecticide use. Furthermore, Berndt & Wratten (2005)[12] highlighted the enhanced lifespan and fecundity of *Dolichogenidea tasmanica*, a key parasitoid of leaf roller (*Epiphyaspost vittana*) in vineyards in and around blooming buckwheat, where the rate of parasitism escalates and densities of leaf-roller decline. In a similar manner, enhanced predators (*Orius* spp., Syrphids and Coccinellids) population and thrips abundance were reported in the insectary and at 30 m and 60 m far from it by Nicholls et al. (2001).[49]

6. *Windbreaks*: Windbreaks and shelterbelts of tall-growing multi-purpose tree species often planted to minimize the wind velocity also act as alternate hosts and harbor several natural enemy species. These are identical to hedgerows but are more effective in reducing wind speed and providing larger amounts of foliage to shelter natural enemies. Carabids and staphylinids (Coleoptera) are natural enemies of agricultural pests and were found more abundant on the edges of shelterbelts/windbreaks as compared to the interiors of the multi-row windbreaks.[41] Since the edge of windbreaks

of a single-rows constitutes most of the windbreak, carabid and staphylinid density are expected to remain stable in different types of windbreaks.[29]

7. *Corridors*: Historically, conservation biologists have utilized corridors to conserve and maintain biodiversity, ensuring different pathways for the species to circulate, disperse and propagate across the ecologies.[56] Various ecological processes, individuals, and genetic flow can take a pass through corridors across the landscape. The corridors are often used to link animal habitat pieces. Nicholls et al. (2001)[49] observed that different predators on blooms of major corridor plants like fennel (*Foeniculum vulgare*), *Erigeron annuus*, *Buddleja* spp., and yarrow (*Achillea millefolium*), including *Chrysoperla carnea*, *Orius* spp., *Nabis* spp., *Geocoris* spp., and a few members of the families Coccinellidae, Mordellidae, Syrphidae and some species of thomisid spiders. A few predator species were found to be linked/ associated with specific flowering plant species.

Conclusion

According to FAO, by 2050, we need to improve overall food production by 70% to keep up with the growing population all over the globe. At the same time, India is expected to be the most populous country by 2030, with 1.51 billion people. Under such circumstances, providing food security would be one of the toughest challenges for the nation. Therefore, adopting large-scale farming practices or production technologies that are not scientifically proven might harm crop yield and pose severe concerns for the national goal of ensuring food and nutritional security. In the presented article multiple scientific facts are given supporting some aspects of natural farming. Techniques including mulching, crop rotation, application of microbial cultures, intercropping have been proven beneficial to the productivity. Whereas, looking at all the aspects of natural farming, it seems that adopting such practices in rainfed areas can be more beneficial than irrigated areas. In contrast, the whole practice of natural farming includes more laborious work than the other techniques which is a hidden disadvantage of such system. In this situation, it is advised to the farmers to work in groups instead of working as individual units. As per future scope, the authors suggest to investigate the carbon footprints, economic and social impacts, and deeper insights of the natural farming techniques for a better understanding of the target farming systems.

Declaration of interests

The authors have no conflict of interest to declare.

Data sharing

All relevant data are within the manuscript.

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