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Integrating natural farming with agroecology for soil health care under fruit production system

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ABSTRACT

Increasing menace of nutrient mining adversely affecting the soil health, a daunting challenge to neutralize amidst climate change. Of late, natural farming has ignited researchers more intensively. Fruit crops offer a strong sink for sequestration of atmospheric carbon dioxide, thereby, aid in moderating the impact of climate change related issues. The paradigm shift from purely inorganic to either organic fertilizers or in combination with chemical fertilizers and now natural farming formed the basis for natural farming with integration of agro-ecological approaches. Better responsiveness of soil microbial biomass over chemically available nutrient pool of soil has advocated a possibility of using changes in microbial biomass as a potential diagnostic tool of soil fertility measurement. Development of microbial consortium (microbial concoction) exploiting the native and natural microbial synergisms (with twin role as growth promoter and antagonistic to soil borne pathogens) is one of the popular methods of managing multiple soil fertility constraints occurring within the rhizosphere, a concept dictating another version of natural farming embracing agroecology. Retrofitting microbes through the microbial consortium (Aspergillus flavus, MF113270; Bacillu pseudomycoides, MF113272; Acinetobacter radioresistens, MF113273; Micrococcus yunnanensis, MF113274; and Paenibacillus alvei, MF113275) for nutrient requirement is one of the novel approaches of not only ensuring good health of citrus nursery but cutting down the intensity of mortality during planting into new citrus field. Long term evaluation of microbial consortium and rhizosphere hybridization in mature citrus orchards showed much better dividends in terms of better soil health indices coupled with environmental health and quality production. These successful efforts would go a long way in integrating natural farming with agroecological issues in developing a more soil health and nutrient dense fruit crops.

Keywords: Fruit crops, soil health, agroecology, microbial consortium, natural farming, climate change

BACKGROUND

Natural farming is considered another form of regenerative agriculture, which has stronger resilience against climate change-related issues. Needless to say, natural farming integrates five major issues like soil health care, soil biodiversity, crop biodiversity, production stability, environmental health and water quality. Of these, soil health is the central core of the natural farming (Keditsu and Srivastava, 2014). Soil is an environmental medium, playing crucial role in global C cycle (soil C pool as the second biggest carbon pool), mainly through changes in soil fertility (Srivastava and Singh, 2003a; 2003b; 2005). Soil is, therefore, viewed as a part of climate change problem, but it can be a better part of the solution. Besides elevated CO_2, changes in rainfall pattern and increase in average temperatures brought about by climate change with inflict over-riding effects on soil fertility changes vis-à-vis crop performance (Bindi *et al.,* 1997; Bhatnagar *et al.,* 2016). Synergism between the effect of CO_2 and nutrients is stronger under no water limiting conditions. However, such short term changes in fertility dynamics do not portray the long term effect either on soil fertility or on production responses, unless supported by defined analogues of soil and climate (Srivastava and Singh, 2005; 2006). Different fruit crops sequestering 24 – 109 tons CO_2/ ha display their ability to moderate climate change-related issues on one hand, and elevate the crop fertilising ability for improved plant nutrition, besides water-use-efficiency, on the other hand (Centritto *et al.,* 1999a; 1999b). Therefore, response of different fruit crops under elevated CO_2 condition is a function of nutrition status of the crop, where soil microbial ecology plays a pivotal role (Srivastava and Singh, 2008).

Previously, our studies demonstrated the maximum nutrient demand at fruit set stage (March-April for winter crop and August-

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September for summer crop under sub-humid tropical climate of central India). As per crop ontogeny, unless there is some mitigation strategy available of late, certain citrus growing pockets of central India irrespective of orchard nutrient status (possibility of disturbed K metabolism), exhibited abnormal fruit growth (greater growth along equatorial than radial axis), the exact cause and effect relation still remains to be established (Srivastava *et al.,* 2007). A large difference in fertility of two sites (Ustorthent versus Haplustert) indicated by a much greater increase in yield response at the low fertility soil site (Ustorthent) than the high fertility soil site (Haplustert), when added nutrient augmented to the same optimal fertility. But with climate change, such responses will be caused by nutrient limitation that can develop in poor fertility sites having shallow rooting depth. The recommended dose of fertilizers (RDF) worked out in 1990 – 91 is no longer effective now (2010 - 2015), due to rise in average temperature by 1.5 – 2.0^{0}C during fruit set stage, necessitated addition of 25% more K to moderate such temperature stress in citrus (Srivastava *et al.,* 2015). How does RDF behave in the long run in different crops when agroecology is to be integrated with emphasis on microbial turnover of the nutrients. Recognition of the importance of soil microorganisms has led to an increased and thoroughly renewed interest in measuring the quantum of nutrients held in their biomass.

There are ample evidences accrued through worldwide research that nutrient-microbe synergy is the launching pad for any fruit crop to mobilize and accumulate the required nutrients as per the metabolic nutrient demand, a pre-requisite to improved input-use-efficiency. Many genes play a central role in the acquisition and distribution of nutrients, including many protein-coding genes as well as microRNAs (miR395, miR398, miR397, and miR408) reported that higher tolerance to nutrient deficiency could be explained by better activation of their antioxidant system (Chiou , 2007) .

A still bigger question emerges, whether rhizosphere competent microbes could collectively contribute toward improved resilience of plant's rhizosphere against potential nutrient mining (Wu and Srivastava, 2015; Zou *et al.,* 2015; Wu *et al.,* 2019). And if those microbes are so successful in promoting growth response, addition of starter nutrients in such combination may further magnify the magnitude of response called nutrient-microbe synergy (Marschner *et al.,* 2004). Our earlier studies have shown that rhizosphere effective microbes have the tendency to play multiple roles to overcome various biotic and abiotic stresses while interacting with an environment. Rhizosphere modification through roots by soil microorganisms exudation is an important attribute that regulates not only the availability of nutrients in the soil but also their acquisition by plants (Srivastava *et al.,* 2004a; 2004b). Long term data accrued on response of organic manuring versus inorganic fertilizers demonstrated that important soil quality indices like soil microbial diversity, soil microbial biomass nutrient (C_{mic}, P_{mic}, and N_{mic}) and organic carbon partitioning displayed significant changes, but without much difference in quantum of fruit yield. In this background information, an attempt was , therefore , made to analyse the possibilities of integrating natural farming issues with conventional agroecology to sustain the production of different fruit crops in general, and citrus fruits in particular.

NATURAL FARMING, A REGENERATIVE APPROACH

Land degradation (96.4 million ha of degraded land accounting to 29.3% of the country's total geographical area of 328.7 million ha) neutrality has been one of the prudent strategies of national agriculture policy where coalition of conventional and traditional farming takes place with singular objectivity of sustainability through regenerative agriculture. In a way, regenerative agriculture (no legal or regulatory definition of term "regenerative agriculture" exists nor has a wide accepted definition emerged in common usage) is firmly rooted to the same basics of modern form of agriculture (using conservation and rehabilitation approach for sustaining the top soil fertility functions, frequently coined as quite opposite to conventional agriculture), addressing core issues like natural resource conservation, soil microbial diversity, resilience against forging climate change, expanding water intake capacity, scavenging soil contaminants, usage of cover crops (field buffers and plant strips on contours) for reduced run-off loss and maintaining the environmental health as well, but it emphasizes more firmly the rejuvenation of depleted land from physical, biological and chemical barriers restricting the targeted optimised crop agronomy and aid further in recuperating the full potential for crop carrying capacity of a given land or land use in a farming system module. Regenerative agriculture recognizes all sustainable practices those affect the natural systems and uses all the management techniques to restore the system towards improved crop productivity (Srivastava and Singh, 2009). Despite these accruing benefits, regenerative agriculture is often associated with number of disadvantages like need for new knowledge and skills, excessive weeds infestation and potentially lower crop yields. However, regenerative agriculture is applicable to all types of farms, big, small or organic in nature. The term “Regenerative Agriculture” came into existence by Robert Rodale Institute in 1980s. India made some modest contribution to realise the strength of this form of sustainable agriculture through i. national project on organic farming , ii. Systematic rice intensification and iii. Zero budget natural farming.

Natural farming on the lines of regenerative agriculture also into account towards sequestering atmospheric carbon into the annual/perennial framework of crops as well as soil , so that atmospheric CO_2 offset is exercised through two-way process, offering carbon neutral approach amidst climate change .The importance of regenerative agriculture was prominently emphasized in Intergovernmental Panel on Climate Change enlisting ecological functions in building resilience of agro-ecosystems as climate –smart regenerative agriculture. On the other hand, no scientifically structured studies have been conducted on water –use-efficiency and water savings in relation to natural or regenerative agriculture. Replacing water guzzling crops like rice, wheat, sugarcane with comparatively less water requiring crops like gram and chickpeas alone saved 5.5 billion litres of water. Trials on regenerative agriculture (as a water stewardship plan) in states like Madhya Pradesh and Maharshtra have saved 15 billion litres of water , helping 110 billion urban and 270 billion rural people according to 2022 edition of Down-To-Earth. These statistics reveal volumes about the magnified impact of regenerative agriculture reaching out to reduction in water foot prints of agriculture offering carbon trading in international market.

Regenerative agriculture is very often compared with organic agriculture. Both the concepts have some difference with a common goal of outcomes on ecological balance and biological diversity, leading to emergence of another concept called regenerative organic agriculture. The regenerative agriculture (about principles not practices as adaptive management approach supported by soil health principles) is based around observable improvements in ecological and social function of the farm and farming community, while organic agriculture(prescriptive standards for crop production) is more about a set of rules to follow with major emphasis on avoidance of agrochemicals. Interestingly, the technique of cover cropping as a part of regenerative agriculture, the definition remains murky, and many other beneficial practices are in a grey area covering the legal definitions, certification and clear methods of measurements and monitoring (Srivastava *et al.,* 2002). On the other hand, organic farming may not have a specific definition, but certifications at least provide a clear understanding about the required practices to adopt.

While comparing regenerative agriculture with organic agriculture, both often connected with natural farming, we comprehensively overlook the harmful effects of organic pesticides, could be even more harmful than synthetic pesticides in organically produced fruits and vegetables for example as wide spread myth. Are natural pesticides safer than artificial pesticides?. The candid answer is, not necessarily. Comparing copper sulphate and pyrethrum with synthetic pesticides like chlorpyrifos or chlorothalonil, the former have more acute and chronic toxicity over latter group of pesticides These scientific outcomes put an alarm bell to researchers and policy makers to keep a regular guard on health of agro-ecosystem, the modus-operandi of which need to be developed and put to stringent practice (Srivastava *et al.,* 2021).

Role of organic manures and composts, biochars and terra- preta, no till and pasture cropping, annual organic cropping, holistic management of grazing, ecological aquaculture, perennial cropping, silvipasture and agroforestry, all aid in developing a sound success of regenerative agriculture vis-à-vis natural farming (Mousavi et al. 2022). Of late, some novelties have emerged suiting to regenerative agriculture, comprising microbial consortium (developing synthetic microbes using synonymous molecules of secondary metabolites secreted by different microbes participating in both plant growth regulation as well as microbial bioagents) exploiting varied microbial niches of phytobiome to develop microbes- mediated crop production system, rhizosphere hybridization for developing more biochemically active rhizosphere through elevated loading of active and novel microbes, on-farm organic module for organic farm waste recycling and exploiting the rhizosphere and endosphere microbial diversity, in addition to bioprospecting microbiome for soil health-plant health management addressing both soil fertility constraints and plant diseases as a value –chain –management of microbes. Development of crop-based soil health card addressing biological improvements in soil health in response to regenerative agriculture is another futuristic pivotal agenda (Jeyabaskaran *et al.,* 2021).

EXPLOITING PHYTOBIOME FOR SOIL HEALTH -INDUCED PRODUCTION

Plant phytobiome posing microbial diversity through different microbial niches comprising rhizosphere and endosphere offer the best opportunity to develop and upscale the combination of rhizo-competent microbes, popularly called as microbial consortium or microbial concoction. The most common objective of developing microbial consortium is to capitalize on both the capabilities of individual microbes and their interactions to create useful systems in tune with enhanced productivity, and soil health improvements through efficient metabolic functionality. Two major underlying principles are applied in the whole process of development of microbial consortium (Lotka, 1992; Brauer *et al.,* 2012). The first one is resource ratio theory which uses both qualitatively and quantitatively to assess the outcomes between component microorganisms competing for shared limiting resources. This permits coexistence of multiple microbes or the competitive exclusion of all but a single microbe. And the second principle theory relevant to microbial consortium is maximum power principle initially proposed and later modified at various levels, is value for analyzing consortial interactions. It also dictates that biological systems that maximize fitness by maximizing power, is analogous to metabolic rate or the capacity to capture and utilize energy. Many of the past studies (Handelsman *et al.,* 1998; Kim *et al.,* 2008; Klitgord and Segre, 2011) put forth the basis for classifying microbial consortium as : i. artificial (carrying two or more wild type microbes whose interactions do not typically occur naturally), ii. synthetic (carrying microbes which are modified through manipulations of genetic content) and iii. natural (carrying microbes having much wider applications like bioremediation, wastewater treatment, biogas synthesis etc.). In the past, a number of studies have suggested the coinoculation of different microbes, which can be summarized as: *A. brasilense* – *P. striata*/*Bacillus polymyxa*, *A. lipoferem* – *Agrobacterium radiobacter*/*A. lipoferem-Arthrobacter mysorens*, *A. brasilense* – *Rhizobium*, *A. brasilense* – *A. chroococcum* – *Klebsiella pneumoniae* – *R. meliloti*, *A. brasilense* – *R. leguminosarum*, and *A. brasilense*/*Streptomyces mutabilis*– *A. Chroococcum* (Alagawadi and Gaur, 1992; Belimov *et al.,* 1995; Yadav *et al.,* 1992; Fabbrie and Del Gallo, 1995; Hassouoma *et al.,* 1994; Neyra *et al.,* 1995; Elshanshoury, 1995). The microbes involving AM -fungi and bacteria have also been suggested for improvement in both yield and quality. These include: *A. brasilense* – *G. fasciculatum*in wheat (Gori and Favilli, 1995), strawberry (Bellone and de Bellone, 1995), *A. brasilense* – *Pantoeadispersa* in sweetpepper, and A*. chroococcum* – *G. mosseae* in pomegranate (Aseri *et al.,* 2008).

We carried out studies with an aim to develop rhizosphere specific microbial consortium. Growth promoting microbes were isolated from rhizosphere (0-20 cm) for development of microbial consortium through extensive soil sampling (from the rhizosphere of as many as 110 plants) at the experimental site. The microbial diversity existing within rhizosphere soil was isolated following standard procedures, and characterized the promising microbes for their nutrient mobilizing capacity through laboratory-based incubation study using the same experimental soil. The efficient microbes viz., *Aspergillus flavus* (MF113270, P-solubilizer), *Bacillus pseudomycoides* (MF113272, K- solubilizer), *Acinetobacter radioresistens* (MF113273, N- solubilizer), *Micrococcus yunnanensis* (MF113274, P-solubilizer) and *Paenibacillus alvei* (MF113275,P-solubilizer) were finally identified. Pure culture of these microbes in value added form was developed in broth, and prepared a mixture called microbial consortium. The compatibility amongst these microbes was tested by thoroughly their population dynamics in consortium mode which showed no antagonism amongst them upto 210- days of laboratory oriented incubation study (Srivastava *et al.,* 2014).

RETROFITTING MICROBIAL CONSORTIUM IN CITRUS NURSERY

The microbial response study was carried out over the acid lime seedlings at pre-evaluation stage (Primary and secondary stages of nursery management) after its morphological and biochemical identification. In the experiment, the progressive response of multiple microbes of the microbial consortium was tested without addition of any inorganic fertilizers through soil inoculation, different microbes were inoculated into the soil (Growing medium) on a month old seedlings of acid lime.

Response in primary nursery: A nursery experiment was set up at ICAR-CCRI Experimental Farm, Nagpur, to observe the progressive response of different microbes on germination rate of acid lime seeds and subsequent growth. Different treatments consisted of:T_1 (Control), T_2 (*Ar, Acinetobacter radioresistens,* MF113273*)*, T_3 (*Ar, Acinetobacter radioresistens,* MF113273 + *My, Micrococcus yunnanensis* MF113274), T_4 (*Ar, Acinetobacter radioresistens,* MF113273)+ *My, Micrococcus yunnanensis,* MF113274 + *Bp,Bacillus pseudomycoides,* MF113272), T_5 (*Ar, Acinetobacter radioresistens,* MF113273) + *My, Micrococcus yunnanensis,* MF113274 +*Bp, Bacillus pseudomycoides,*MF113272) + *Pa, Paenibacillus alvei,* MF113275) and T_6 (*Ar, Acinetobacter radioresistens,* MF113273) + *My, Micrococcus yunnanensis,* MF113274 + *Bp, Bacillus pseudomycoides,* MF113272) + *Pa, Paenibacillus alvei,* MF113275) + *Af, Aspergillus flavus,* MF113270) and replicated four times in a CRD experimental design. Microbial treatment as per treatment was applied to the soil over a month old acid lime seedlings (100 ml) and after 8 days another 100 ml microbial treatment was applied as per the treatment. Response of these microbes was evaluated for changes in germination rate at every 10 days' interval (till 100 days), changes in available nutrient status of soil, leaf nutrient status and microbial status to quantify the magnitude of response with various treatments. The significant response reported over the germination of acid lime seedlings at the various days of observation. The germination rate was reported as high as 79.8 % with treatment T_6 at 100 days of observation with seed viability index of 3.20 followed by the treatment T_4, T_5, T_3, T_2 and T_1 respectively in a decreasing order (Table 1). The maximum rate of seed germination was reported within 30 days of observation amongst all the treatments. The seed germination percentage of the treatments T_4 and T_5 was on par with each other depicting the relatively similar response on the growth and development of the growing seedlings in response to added microbes.

Growth response in secondary nursery: Different growth parameters (Shoot parameters viz., shoot length, shoot weight, number of leaves, girth and plant and root parameters viz., root length and root weight) were recorded following the transfer of seedlings from primary nursery to secondary nursery. These growth parameters were significantly affected by treatments (Table 2). The shoot parameters observed higher with the treatment T_6 followed by the treatment T_5, T_4, T_3, T_2 and then control in a decreasing order. The shoot length of the treatments T_4, T_5 and T_6 was on par with each other However, root length and root weight was almost statistically on par with all the treatments, except control, indicating an active response on the root density of the seedlings under the respective treatment. Hence, our studies established that microbial consortium can be effectively retrofitted replacing conventionally used chemical fertilizers in nursery, considering very low nutrient requirement of such juvenile citrus plants. There is every possibility, we can further rationalize the use of function specific microbes as per growth stages of nursery plants (Wu *et al.,* 2013; Wang *et al.,* 2014). However, no distinction in morphological or physiological growth behavior exists in nursery plants, right from growth in primary nursery to secondary nursery. And, morphologically, it is very difficult to identify such shifts in growth stages.

Table 1: Changes in germination percentage of acid lime seeds in response to different treatments involving various microbial inoculants

Treatments	Changes in germination percentage (days)										Seed viability index
	10	20	30	40	50	60	70	80	90	100	
T_1 (Control)	15.3	20.1	32.5	39.4	39.4	39.4	39.4	39.4	39.4	39.4	1.05
T_2 (*Ar*)	12.5	18.2	35.6	40.5	40.5	40.5	40.5	40.5	40.5	40.5	1.13
T_3 (*Ar+My*)	17.3	21.3	46.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2	1.79
T_4 (Ar+*My +Bp*)	13.2	19.2	62.5	65.5	65.5	65.5	65.5	65.5	65.5	65.5	2.39
T_5 (*Ar+My +Bp+Pa*)	14.3	20.9	70.3	70.3	70.3	70.3	70.3	70.3	70.3	70.3	2.67
T_6(*Ar+My+Bp+Pa +Af*)	15.7	23.7	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	3.20
CD(*P=0.05*)	NS	1.8	2.8	6.1	5.3	5.4	5.9	5.8	6.1	6.4	-

Ar,My, Bp, Pa, Af, stand for Acinetobacter radioresistens (MF113273), Micrococcus yunnanensis (MF113274)Bacillus pseudomycoides (MF113272), Paenibacillus alvei (MF113275) and Aspergillus flavus (MF113270) respectively.
Note: Seed viability index was calculated at 100 days of germination as Germination percentage × Average seedling length (mm)/100

MICROBIAL RESPONSE OF RHIZOSPHERE HYBRIDIZATION

Artificially, the rhizosphere can be modified or reconstruct as per the need the of plant to enhance the physiological efficiency by rhizosphere engineering, rhizosphere hybridization, creating an artificial environment suitable for the plant growth-promoting microorganisms (PGPMs) to surplus a protective layer against the pathogenic microbes (Rhizosphere fortification), or by various agronomic practices. Rhizosphere hybridization is new concept to modify the rhizosphere ecology to create an optimum environment for PGPMs to show the positive effect of plant agronomy (Srivastva, 2010a; 2010b).

Table 2: Growth response of acid lime seedlings in response to different microbial inoculations (Period: 120 days)

Treatments	Shoot parameters				Root parameters	
	Shoot length(cm)	Shoot weight(g)	No. of leaves/plant	Girth (mm)	Root length (cm)	Root Weight (g)
T_1 (Control)	16.9	1.70	17	1.60	9.8	0.36
T_2 (*Ar*)	17.5	2.23	22	1.79	10.6	0.42
T_3 (*Ar+My*)	18.9	2.90	26	2.30	16.9	0.53
T_4 (Ar+*My +Bp*)	21.0	3.60	32	2.92	17.0	0.75
T_5 (*Ar+My +Bp+Pa*)	21.8	3.09	30	2.80	16.0	0.66
T_6 (*Ac+Pf +Bm*+Pa+*Af*)	22.7	3.72	34	2.75	17.5	0.79
CD(*P=0.05*)	0.40	0.23	03	0.10	0.72	0.04

Ar,My, Bp, Pa, Af, stand for Acinetobacter radioresistens (MF113273), Micrococcus yunnanensis (MF113274)Bacillus pseudomycoides (MF113272), Paenibacillus alvei (MF113275) and Aspergillus flavus MF113270) respectively

The concept of "rhizosphere hybridization" is therefore, advocated to harness the value added benefit of nutrient-microbe synergy, besides providing dynamism to microbial consortium suiting to wide range of perennial fruits.Our studies on response of different treatments involving rhizosphere soil of three perennial trees viz., *Ficus racemosa* L. (Umber tree), *Ficus benghalensis* L. (Banyan tree), and *Ficus religiosa* L. (Pipal tree) along with rhizosphere soil of healthy and highly productive sweet orange trees in sweet orange buddlings showed differential response in terms of agronomic parameters, changes in soil physical properties, and pool of plant available nutrients. However, hybridized rhizosphere of sweet orange and *Ficus racemosa* L. out-smarted the response over other rhizosphere hybridization treatments (Srivastava *et al.,* 2021). These studies lend some support to the fact that inoculation of soil or crops with rhizospheric or endophytic microbes, respectively, can enhance the micronutrient contents in various plant tissues including roots, leaves, and fruits. In field , the rhizosphere hybridization can be implemented by collecting rhizosphere soil of healthy trees and injected into weaker trees to rationalise distribution of microbes across field /orchard as a part of natural farming with agro-ecology exploited as its best (Srivastva, 2015; Srivastva and Singh , 2008.

With these efforts, we succeeded in answering some popularly raised questions summarised as: i.microbes can replace nutrients requirement of citrus nursery, considering absymally low nutrient requirement of nursery plants; ii. Microbial consortium is a far better choice than individual microbe(s); iii. liquid formulation of microbes is better than substrate-based inoculants , either individual microbe or consortium of microbes ; iv. the quantity of microbial broth needs to be standardized for containerized citrus nursery versus field nursery; v. inoculation of citrus nursery plants with microbial consortium needs to be standardized depending upon substrates used (solarized soil versus soilless medium); vi. the treatment of microbial consortium (5ml/plant) reduced the rate of mortality of citrus nursery plants to bare minimum, once transplanted in new orchard site (Srivastava and Singh, 2008 ;Srivastava and Patil, 2014) . This is an excellent piece of information, otherwise orchardists are fed up with high rate of mortality of citrus nursery plants; vii. treatment with microbial consortium provided an additional plant immune on account of biopriming effect of microbes, which eventually aided in far better withdrawal of nutrients from soil and ensured better plant health in ultimate terms; viii. the treatment with microbial inoculants individually or as microbial consortium has a strong promise to be integrated with irrigation (using water extract of healthy rhizosphere either alone or in combination with cow urine , water extract of dung or mixture of water extract of healthy rhizosphere and fish pond water designed to suit natural farming) to evolve a new concept called “biofertigation”for exclusively citrus nursery and ix. use of microbial inoculants can be tailored in citrus nursery, depending upon contrasting growth stages (initiation, establishment and growth stages, though these stages are poorly differentiated and quite inter-changeable).

EPILOGUIE

The biggest practical limitation with natural farming like regenerative agriculture is prudent lack of any well accepted legitimate definition (no doubt, it seeks to rehabilitate and enhance agro-ecosystem as a whole) to practice either areawide or cropwide. However, it is every likely that the punch of outcomes of such practices could be diluted over time, thereby goes to extinction or overtaken by some other concept , since many of terms like agro-ecological farming, alternate agriculture, alternate, sustainable agriculture, nature inclusive agriculture, green agriculture, biodynamic agriculture etc are often used synonymously to challenge the outcomes of regenerative agriculture. Unless, we adhere to such policy regulations, we will not be able to harness the real impact of regenerative agriculture as holistic approach and make further inroads through scientific funding and pan-India collaborative research networking.

A cultivar evaluated under both intensive farming, organic farming or natural farming system may not perform with similar magnitude of success. The major difference lies with respect to differential soil health indices, which are yet to be streamlined, while talking about Soil Health Card. Do we need to breed the fruit crops specifically tailored to such forms of farming (molecular approach to breeding of mineral deficiency resistance and mineral efficiency would facilitate produce nutritionally efficient biotypes in order to maximise the quality production of fruit crops on sustained basis), the answer is wrapped in an enigma for researchers to either refute such hypothesis or accept with sound scientific database proof. Another issue that keeps haunting is the strong necessity of developing on-farm module of natural farming, like organic farming, unless we succeed in these attempts, we will continue using natural farming more like a revitalistic model rather than forward looking agriculture model with more emphasis on genetic, functional and metabolic diversity of soil microorganisms within the rhizosphere of wide range of fruit crops (Srivastava and Singh, 2007; Srivastava *et al.,* 2015). The capacity of soil microbial communities to maintain functional diversity of those critical soil processes could ultimately be more important to ecosystem productivity and stability than mere taxonomic diversity. In this context, it remains to be assessed how nutrient-microbe synergism is associated with productivity of perennial fruit crops.

The framework on soil biodiversity effects from field to fork comprises: i. recognizing both direct and indirect mechanisms of soil biodiversity effects on crops properties, ii. Identifying postharvest processes that affect biodiversity legacy effects on crop properties; and iii. pinpointing biodiversity-related crop properties that influence the efficacy and success of operations occurring in the agrifood chain (Rillig *et al.,* 2018). We also need to validate natural farming concepts more scientifically and spatio-temporally to instill better popularity amongst fruit growers. Sooner we do it , better it is for the future health of contemporary agriculture (expanding agriculture to newer land is almost bare minimum and arresting further land degradation with lowered carbon-and water foot-prints is a numero-uno priority of policy makers) to feed our ever-growing population, soon surpassing the population of China. Therefore , a complete technical and scientific dos and don't with clear-cut policy paper on Natural Farming as Regenerative Agriculture in Indian context is the call of the day, considering our current agriculture system is already so over-worked , over-used and depleted looking at future daunting challenge of feeding 1.40 billion people

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