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Organic farming in rainfed areas of India: A review

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ABSTRACT

India is bestowed with a lot of potential to produce all varieties of organic products due to its various agro-climatic regions and traditional knowledge. Rainfed areas are reported to have relative advantage to go for organic farming primarily due to low level of external input use, shorter conversion period and smaller yield reductions compared to irrigated areas. Several studies have reported improved crop yields and economics under organic management in rainfed areas. Furthermore, farming practices such as organic agriculture that preserve soil fertility and maintain or even increase organic matter in soils are in a good position to maintain productivity in the event of drought, irregular rainfall events with floods, and rising temperatures. Therefore, organic agriculture is one of the adaptation strategies that can be targeted at improving the livelihoods of rural populations that are especially vulnerable to the adverse effects of climate change and variability.

***Key words*:** Climate change, Organic farming, Rainfed areas

Rainfed agriculture is predominant in arid, semi-arid and sub-humid regions of the country and has a crucial role to play in sustaining the economy and food security of India. At present, about 51% of the net sown area is rainfed contributing 41% of the total food production, supports 40% of human and 60% of livestock population. These areas contribute almost 100% of forest products, 84–87% of coarse grain cereals and pulses, 80% of horticulture, 77% of oilseeds, 60% of cotton, and 50% of fine cereals including rice, wheat, maize, sorghum etc. (Srinivasarao *et al*., 2015). Further, rainfed regions support 60% of livestock and 40% of human population and contribute 40% of food grains and several special-attribute commodities such as seed spices, dyes, herbs, gums etc. Due to yield plateuing in irrigated area in most of the crops, the second green revolution must therefore explicitly embrace rainfed areas with special focus on pulses and oilseeds to ensure nutritional security and agricultural sustainability.

Droughts and famines are the general features of rainfed agriculture in India. The risk involved in successful cultivation of crops depends on the nature of drought (chronic and contingent); it's probable duration, and periodicity of occurrence within the season. Long-term data for India indicate that rainfed areas experience 3-4 drought years in every 10-year period. Of these, two to three are in moderate and one or two may be of severe intensity. The occurrence of the drought is very frequent in the sub-divisions like West Rajasthan, Tamil Nadu, Jammu & Kashmir and Telangana. Very high incidence of drought (>20%) is observed in a few districts in Rajasthan and Gujarat. The incidence is relatively low in the Western ghats, Eastern and North-Eastern India.

The natural resource base especially in rainfed areas has been severely degraded. Degraded soils with high risks of accelerated erosion resulting in loss of fertile surface soil and soil organic C (SOC), are the major constraints. The magnitude of soil loss ranges from 5 to 150 t/ha/year depending upon soil type, vegetation, and slope gradient. While climate change impacts agriculture sector in general, rainfed agriculture is likely to be more vulnerable in view of its high dependency on monsoon and the likelihood of increased extreme weather events due to aberrant behavior of south-west (SW) monsoon. Aberrations in SW monsoon which include delay in onset, long dry spells and early withdrawal, all of which affect the crops, are likely to further increase in future.

A vast majority of farmers in rainfed areas practice low or no external input farming which is well integrated with livestock, particularly small ruminants. Based on several surveys and reports, it is estimated that up to 30% of the

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rainfed farmers particularly in many remote areas of the country do not use chemical fertilizers and pesticides. Thus, many resource-poor farmers are practicing organic farming by default. The Government of India task force on organic farming and several other reviewers has identified rainfed areas and regions in north-east as more suitable for organic farming in view of the low input use (GOI, 2001; Ramesh *et al*., 2005). Unlike irrigated areas, where homogenous, highly intensive cropping systems are common; rainfed farming systems are more diverse and heterogenous. Coarse cereals, pulses, oilseeds and cotton are the major cropping systems. Livestock farming plays an important role in farmer's livelihood. Historically, rainfed farmers followed a low intensive sustainable farming system with excellent integration of crops-trees-pastures and livestock (Venkateswarlu, 2008).

However, crops like cotton, hybrid sorghum and millets, ground nut, pigeon pea receive relatively higher levels of chemical fertilizers and pesticides all over the country. The chemical input use increased where the varietal replacement was high and greater accessibility to farmers for surface or ground water for protective irrigation. Therefore, it is essential to delineate different regions and crops within rainfed areas depending on the nature and level of input use, so that a proper research and policy initiative can be taken up for identifying prospective regions/commodities (Venkateswarlu, 2008).

Focus on niche areas and commodities

Rainfed areas are reported to have relative advantage to go for organic farming primarily due to i) low level of input use, ii) shorter conversion period, iii) predominantly multiple diverse cropping/integrated farming systems, and iv) smaller yield reductions compared to irrigated areas. However, we cannot suggest any large-scale conversion in view of several limitations particularly availability of organic amendments in required quantities (Venkateswarlu, 2008).

The inherent advantages of rainfed areas should be capitalized by encouraging organic farming in highly selected areas and commodities with edapho-climatic and price advantages. The primary focus should be on commodities which have export potential with price premiums. A list of such crops and the suggested areas are given in Table 1.

Organic farm management

Organic farm management is focused on the whole farm system and its interactions with climate, environment, social, and economic conditions, rather than considering the farm as comprised of individual enterprises. Crop production in organic systems is characterized by an increased diversity of cropping patterns in time and in space compared to intensive conventional crop production systems. The major objectives of such diversity are to operate a closed system for nutrients and organic matter and maintain crop health.

Adoption of soil and water conservation measures, a key component of rainfed farming is also one of the pillars of organic farming. Mulching or mulch cum manuring, residue management, green leaf manuring, cover cropping are other strategies that conserve moisture and improve nutrient use efficiency in drylands which are also the essential components of organic production methods. The use of FYM or other organic nutrient sources during aberrant rainfall years in particular have an additional advantage of protecting the crop from drought besides the nutritional benefits, so critical in drylands.

Table 1. Selected list of commodities with potential for organic production in rainfed regions

Commodity	Scope/opportunity	Potential area
Cotton	Demand for organically produced lint To cut down on chemical use	Maharashtra, Andhra Pradesh, Karnataka, Gujarat
Sesame	Demand for organic sesame seed for medicinal and confectionery uses	Gujarat, Rajasthan
Niger	Demand for niger seeds produced organically for bird feed in Europe	Tribal areas of different states, in particular Odisha and Chhattisgarh
Lentil	Preference for Indian lentil in world markets; organic product to fetch price premium	Uttar Pradesh
Safflower	Growing market for safflower petals as natural food dye and herbal products	Maharashtra
Fingermillet	Scope to export fingermillet flour as health food ingredient	Karnataka, Odisha, Jharkhand
Medicinal herbs	Need for residue free crude drugs	All over India
Ginger/Turmeric	Demand for residue free spices/natural colours	Odisha
Groundnut	To produce residue/toxin free table varieties	Gujarat
Soybean	Demand for organically produced DOC for livestock feed	Madhya Pradesh

(Source: Venkateswarlu, 2008)

Influence of organic management on crop productivity during transition period

Several studies have reported lower yields in organic conditions with comparison to chemical fertilizers (MacRae *et al*., 1993; Saha *et al*., 2007; Gopinath *et al*., 2008, 2009a, 2009b). Initially lower yields on organic farms have been attributed to the negative effects of conventional practices on the soil microorganisms that mineralize soil organic matter, or that control soil-borne pests (Martini *et al*., 2004). Finger millet and lentil require lower levels of nutrients and are generally grown under rainfed conditions. They performed comparatively better under organic management than other crops during conversion period (Mahanta *et al*., 2021). On average, finger millet gave 9.3% reduction in yield under organic management compared with conventional practice during initial two years. The reduction in lentil yield, however, was only 3.6%.

Farmyard manure (FYM) and vermicompost (VC) were evaluated against the recommended NPK (20-80-40 and 60-30-20 kg N-P_2O_5-K_2O/ha, for rainfed soybean and wheat) under rainfed soybean-wheat cropping system during the transition phase for conversion to organic. The potential wheat equivalent yield of soybean-wheat cropping system through FYM and VC were 10,971 and 11,171 kg/ha, which could be achieved with application of 57 and 55 kg P/ha, respectively (Mahanta *et al*., 2021). These yield levels were 40 and 43% higher than the recommended NPK, respectively. The level of P required from FYM and VC to achieve the same yield level as recommended NPK for rainfed soybean-wheat cropping system were only 8.6 and 8.0 kg P/ha, respectively, which were very less compared to 24.0 kg P/ha (mean of 34.9 and 13.1 kg P/ha under recommended P through inorganic (SSP) for soybean and wheat crop, respectively).

Different nutrient sources were evaluated for finger millet + black soybean (2:1) - wheat + *toria* (2:1) and grain amaranth-wheat + lentil (2:1) under rainfed system. Application of 100% N equivalent through FYM produced highest grain yield of all crops during the transition period (Mahanta *et al*., 2021). The grain yield with the application of 100% N equivalent through FYM provided 36-118% higher grain yield compared to the recommended NPK during the transition period. The results were also similar after the transition period.

Selection of crop varieties

Crop improvement efforts during the second half of 20th century has been focused almost entirely on breeding for conventional farming systems. Conventional varieties have been developed with the aim of combining high productivity and standardized product quality under high-input conditions. The consequence is that organic farmers have to depend on varieties bred for cultivation with high external inputs. The amount of stress on the crop is expected to be more under organic management than under input-intensive conventional farming. The stress may be in the form of available nutrients, weed pressure, insect-pests and diseases. Varieties are needed that can respond to the sometimes sub-optimum conditions (typical of organic farming conditions). Therefore, choice of variety is more critical in organic situations than for conventional crops where problems can be solved at a later stage by application of pesticides or mineral fertilizers. Level of resistance to diseases and insect pests must be a criterion while selecting the variety for organic farming. Yield, quality, and market acceptability also have to be considered while selecting crop varieties.

Suitable varieties of different crops have been identified for rainfed organic farming in Northwestern Himalayan states, based on field trials conducted at Viveanda Parvatiya Krishi Anusandhan Sansthan, Almora (Mahanta *et al*., 2021). Ramesh *et al.* (2006) evaluated four varieties of pigeonpea under organic management at Indian Institute of Soil Science (IISS), Bhopal. Among the four varieties, ICPL-87119 recorded the highest number of pods/plant, 100-seed weight, seed and stalk yield. Jowahar-4 and Asha gave similar but significantly higher seed yields than BDN-2.

Performance of different crops/cropping systems under organic management

Several studies have reported varied performance of different crops under organic management (Table 2). Similarly, many researchers have also reported better nutritional quality of organic produce compared to that of conventional produce.

Millets

Supply of nutrients to barnyard millet (*Echinochloa frumentacea*) exclusively through organic sources adequately supports the crop growth and yield, due to comparatively low nutrient requirement of the crop. In a field experiment at Ranichauri (Uttarakhand), various organic nutrient sources gave significantly lower productivity of barnyard millet than recommended dose of fertilizer (RDF) treatment in the initial two years (Yadav and Malik, 2010). However, from third year onwards, organic treatments involving vermicompost (VC) + wild apricot-cake, WAC (50% N from each source) with and without *Azotobacter* produced similar grain yields as that of RDF treatment. Among the treatments involving organic manures, VC + WAC (50% N from each source) + *Azotobacter* on

Table 2. Performance of different rainfed crops under organic management

Crop	Location	Best treatment	Key results	Reference
Finger millet	Shivamogga, Karnataka	FYM (7.5 t/ha) + 100% N equivalent vermicompost (4 t/ha)	Higher grain yield, straw yield, sustainable yield index, improved soil organic carbon and microbial population.	Ullasa *et al*. (2020)
Barnyard millet	Ranichauri Uttarakhand	Vermicompost + wild apricot-cake, WAC (50% N from each source) + *Azotobacter*	Higher grain yield	Yadav and Malik (2010)
Rainfed lowland rice	Sirsi, Karnataka	100% N through organic manure + 100% organic plant protection measures	Organic rice yields were at par with INM from 6th year	Manjappa (2023)
Pigeonpea	Hyderabad, Telangana	FYM 4 t/ha (100% N equivalent)	Higher seed yield and nutritional quality	Gopinath *et al.* (2023)
	Tamil Nadu	FYM (2.5 t/ha, 50% N equivalent) + vermicompost (0.416 t/ha, 50% N equivalent)	Higher growth parameters and yield compared to control	Vanathi and Balaganesh (2024)
Watermelon	Parbhani, Maharashtra	100% RDN through FYM + biofertilizer (*Azotobacter*)	Higher number of fruits per vine and fruit yield per vine compared to chemical treatments.	Kharat *et al*. (2020)
Green gram	Hyderabad, Telangana	FYM 4 t/ha (100% N equivalent)	Higher seed yield and nutritional quality	Gopinath *et al*. (2023)
	Prayagraj Uttar Pradesh	5% Panchagavya + 3% Vermiwash + 5 t/ha FYM	Higher seed yield, stalk yield, and pods per plant	Reddy *et al*. (2022)
Soybean	Himachal Pradesh	Vermicompost (10 t/ha) + three vermiwash sprays	Higher seed yield and superior growth parameters.	Awasthi *et al*. (2020)
Cowpea	Palampur, Himachal Pradesh	FYM (10 t/ha) + Ghanajiwamrita (250 kg/ha)	Higher yield and nodules per plant	Sharma *et al*. (2023)
Sesame	Vridhachalam, Tamil Nadu	FYM (12.5 t/ha) + *Azospirillum*, Phosphobacteria, PGPR (600 g/ha) + foliar Panchagavya (3%) at 35 and 45 DAS	Higher seed yield	Chandrasekaran *et al*. (2024)
	Hyderabad, Telangana	FYM 3.7 t/ha + neem cake 900 kg/ha + ash 75 kg/ha + bone meal 75 kg/ha + elemental sulphur (ELS) 20 kg/ha + PSB 5 kg/ha (soil application) + *Azotobactor* 5 kg/ha, and pest management with *Trichoderma* (0.4%) seed treatment + neem oil spray thrice at 15, 30 and 45 DAS, and *Azadirachtin* (0.03%) spray at 30 DAS	Seed yield was low during initial three years but gradually increased under organic management	Gopinath *et al*. (2009a)
Guava	Lucknow	Amritpani + 250 g rhizospheric soil of *Ficus benghalensis* + organic mulching	Maximum return: 1,27,746/ha, B:C ratio: 4.4.	Ram and Pathak (2019)

an average produced statistically similar yield (1.78 t/ha) as that of RDF treatment (1.92 t/ha). Similarly, Prabhakar *et al.* (2023) found that substituting FYM for fertilizers, fully or partially, enhanced growth, yield, N uptake, and N use efficiency, with the order: 100% RDN as FYM > 50% RDF + 50% RDN as FYM > 100% RDF. The soil organic carbon, available N, P, K, and S improved by 25.0, 12.9, 5.7, 6.1, and 22.6%, respectively under higher FYM application (8 t/ha) compared to chemical fertilizers alone. In another study, application of FYM (7.5 t/ha) combined with 100% N equivalent vermicompost (4 t/ha) yielded the best results in finger millet, including the highest grain yield (25.81 q/ha), straw yield (54.69 q/ha), tillers per hill (4.88), finger length (9.5 cm), and yield per plant (15 g). This treatment also achieved the highest sustainable yield index (81.43%), enhanced soil organic carbon, and supported the largest microbial population compared to the initial soil status and other nutrient management practices (Ullasa *et al*., 2020).

Legume crops

In a long-term experiment at ICRISAT, Hyderabad, crop yields (pigeonpea and cowpea) in seven out of nine years were similar or higher in the treatments involving low-cost and biological approaches than the treatment ‘conventional agriculture’ on a rain-fed Vertisol (Rupela *et al*. 2005). The results of a 10-year study revealed that, averaged across the years, pigeonpea seed yield (721-737 kg/ha) was similar under both organic and integrated production systems compared to Control (chemical inputs) (672 kg/ha). In green gram, the seed yields were higher under integrated production system during initial 5 years, whereas organic system recorded marginally higher yields during the latter 5 years compared to other treatments (Fig. 1). On average, green gram seed yield (699-706 kg/ha) was similar under both organic and integrated production systems (Gopinath *et al*., 2023). Yadav *et al*. (2023)

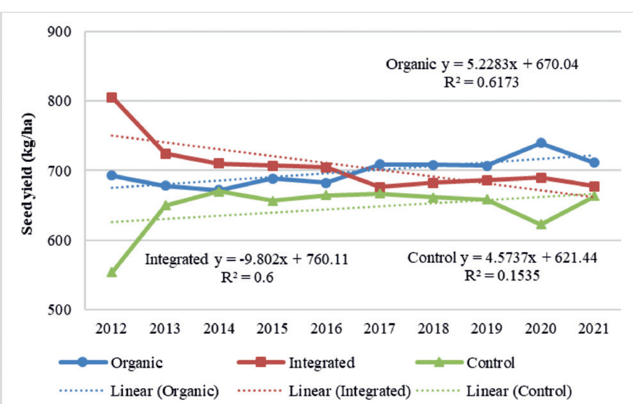

Fig. 1. Performance of greengram under different production systems during 2012-21 (Gopinath *et al*., 2023)

studied the impact of liquid organic formulations on mungbean in Rajasthan and found that two independent sprays of panchagavya and a combined spray of panchagavya + vermiwash significantly improved seed yields (1128 and 1051 kg/ha), net returns (₹55,576 and ₹49,361/ha), and B:C ratios (2.30 and 2.07), outperforming other treatments. Similarly, application of panchagavya + FYM to green gram resulted in significantly higher plant height (62.2 cm), leaf area index (3.61) and dry matter accumulation (288.2 g/m) as compared to other treatments in green gram (Chongre *et al.* 2019).

Oilseed crops

Organic farming in groundnut produced 18.2 and 22.1% higher dry pod yield and higher kernel yield over inorganic farming (2970 and 2345 kg dry pod and kernel yield/ha, respectively) (Malligawad and Parameshwarappa, 2006). Furthermore, groundnut crop in organically amended plot did not show moisture stress during the period of dry spell of 38 days due to greater moisture conservation. However, in a 10-year study at Hyderabad, integrated production system recorded higher seed yield of sunflower in all the years except during last 2 years where seed yield was marginally higher under organic production system than other treatments (Gopinath *et al*., 2023). A gradual improvement in seed yield of sunflower was observed under organic production system whereas, the seed yield showed a declining trend in the plots under Control (chemical inputs), over the years. Similarly, Gopinath *et al*. (2009a) reported that the grain and stalk yields of sesame were higher under conventional farming than that under organic farming and control in all the years. The grain yield reduction under organic farming was 18% in 2005, 22% in 2006 and 20% in 2007 compared with conventional farming.

In recent years, the farmers have switched over to cultivation of soybean under organic farming conditions. There is a global demand for organically grown soybean (Ramesh *et al*., 2006). In a field experiment conducted at IISS, Bhopal, during the first year, conventional farming resulted in higher yield, gross income and benefit cost ratio compared to that of organic farmin. In the second year, both conventional and organic farming resulted in the comparable yields and almost similar economic returns. However, in the third year, organic farming recorded higher yields, gross income and benefit cost ratio compared to the conventional farming.

Tuber crops

Most of the tuber crops are grown by small and marginal farmers in rainfed and tribal areas and hence use of chemical fertilizers and insecticides are limited except in the case of cassava in the industrial production areas of Tamil Nadu (Salem, Dharmapuri, Namakkal, South Arcot districts) and Andhra Pradesh (Rajahmundry district). Tuber crops in general and aroids in particular, like elephant foot yam respond well to organic manures and there is considerable scope for organic production in these crops. Further tropical tuber crops are well adapted to low input agriculture. They are less prone to pest and disease infestations. Three years of experimentation has indicated that organic farming is a viable proposition in elephant foot yam (Suja, 2008). Of the three production systems tested in elephant foot yam (conventional, traditional and organic farming), organic farming proved promising with high yield. In another experiment, three species of yam/ Dioscorea (*D. rotundata* (var. Sree Priya), *D. alata* (var. Sree Keerthi and *D. esculenta* (var. Sree Latha)) were tested under three production systems viz., conventional, traditional and organic farming (Suja, 2008). *Dioscorea rotundata* produced higher yield in conventional practice (19.20 t/ha), which was on a par with organic farming (17.81 t/ha). In the case of *D. alata*, all the production systems were on par; traditional practice (20.64 t/ha) resulted in slightly higher yield than organic (19.46 t/ha) and conventional practices (19.04 t/ha). In *Dioscorea esculenta*, organic farming proved superior (8.58 t/ha).

Medicinal, aromatic and dye crops

The organically grown medicinal plants fetch higher price in the international market and demand for organic product is increasing day by day with increase in awareness of the side effects of the synthetic drugs. In a field experiment conducted at CRIDA, organic fertilizers were applied by equating with recommended dose of Nitrogen (50 kg/ha) in Senna, Andrographis and Ashwagandha. Highest Senna leaf, biomass of Andrographis and Ashwagandha root yields were recorded with the application of vermicompost, neem and castor cakes, respectively (Table 3). The application of castor cake also improved the quality of Andrographis with respect to andro-grapholide content in roots (CRIDA, 2008).

In another experiment, application of tank silt increased the yields of senna and andrographis by 54.8%, 67%, and 33.8% over no tank silt condition (CRIDA, 2008). Application of NPK, castor cake and bio mix (a mixture of *Trichoderma reseii,Phenerochyte chrysosporium, Bacillus subtilis* and *B. coagualans*) recorded higher yield in senna. The increase in yields was observed with application of vermicompost, Biomix, FYM and NPK in andrographis. Biomix application recorded significantly higher root yields of ashwagandha over all the treatments followed by application of NPK. Aromatic plants, however, did not respond well to organic management (CRIDA, 2008). The biomass and oil yields of lemon grass and palmarosa were highest with application of inorganic fertilizers followed by vermicompost and castor cake application. Highest 'citral A' content in lemongrass and 'geraniol' in palmarosa were recorded with vermicompost and castor cake application, and the lowest content in inorganic fertilizer.

Organic farming and climate change

Climate change and variability are a considerable threat to agricultural communities, particularly in India. This threat includes the likely increase of temperature, extreme weather conditions, increased water stress and drought, and desertification. Farmers need tools to help them adapt to these new conditions. Organic farming is one such option which has both climate change mitigation and adaptation potential particularly in rainfed agriculture. It emphasizes recycling techniques and low external input and high output strategies. It is based on enhancing soil fertility and diversity at all levels and makes soils less susceptible to erosion. Emissions of nitrous oxide (N_2O) are directly linked to the concentration of easily available mineral nitrogen in soils. High emission rates are detected directly after fertilization and are highly variable. In a study by Petersen *et al*. (2005), lower emission rates for

Table 3. Influence of organic management on yield and quality of medicinal crops

Treatment	Yield (kg/ha)			Andrographolide (%)
	Senna (Fresh leaves)	Andrographis (Fresh biomass)	Ashwagandha (Dry root)	
FYM	1,517	1,974	817	1.304
Vermicompost	1,926	2,666	632	1.032
Castor cake	1,285	2,258	1,011	1.774
Neem cake	1,750	2,493	512	1.046
NPK	938	1,192	451	1.664
Control	1,314	747	332	1.008
LSD (P=0.05)	407.18	570.7	107.08	

(CRIDA, 2008)

organic compared to conventional farming were found for five European countries.

The use of organic amendments in organic farming not only supply nutrients but also have the potential to contribute to soil carbon sequestration. In a study at Hyderabad, organic production system being on par with integrated production system improved the easily oxidizable, oxidizable and weakly oxidizable organic C fractions at different soil depths compared to control. The C sequestration rate ranged from 0.21 to 0.85 t C/ha/yr in organic production systems compared to negligible rate (0.01–0.04 t C/ha/yr) in the plots under control (Gopinath *et al*., 2022).

Organic agriculture systems have a strong potential for building resilient food systems in the face of uncertainties, through farm diversification and building soil fertility with organic matter (Scialabba and Muller-Lindenlauf, 2010). Several mechanisms may increase drought tolerance of organic cropping systems. Soil organic matter has positive effects on the water-capturing capacity of the soil. Numerous studies have shown soil organic carbon to be higher in organically managed systems (Gopinath *et al*., 2008, 2011, 2023). As a result, organically managed soils have high water holding capacity (Liebig and Doran 1999; Wells *et al*., 2000; Gopinath *et al*., 2022). n India, most of the organic cotton farmers stated that the capacity of their soils to absorb and retain water was increased after conversion to organic management (Eyhorn *et al*., 2009). Many farmers also said that they need less rounds of irrigation and the crops can sustain longer periods of drought.

Constraints in scaling up of organic farming

Besides the well-known limitation of the availability of FYM and other organic forms of nutrients in desired quantities, water availability also is an important constraint for adoption of organic farming, particularly in arid and dry semi-arid tropics. Absence of surplus rainwater for harvesting and long periods of low soil moisture can limit the overall biomass production for recycling, green leaf manuring and on-farm composting. Application of 5-10 t FYM/ha is required in most crops to produce on par yields with recommended chemical fertilizers. Such level of inputs use can only be possible in limited areas for specific crops. However, biomass production during the off-season through a legume cover cropping and its incorporation in the soil can be another strategy to overcome the limitation of organic matter availability in high rainfall regions. Since the overall biomass production is linked to rainfall, using crop biomass either by composting or through recycling should be a major strategy in relatively high rainfall receiving areas in moist semi-arid and dry subhumid regions (750 - 1200 mm) while the dry semi-arid and arid areas (300 - 750 mm) may depend on use of FYM as the principal source, since livestock is a strong component in these regions.

Considering the low organic matter and fertility status of Indian soils, the yield decline during conversion period could be sharp in the absence of external inputs. In view of the limited biomass and organic resources available for use in rainfed areas, organic production either for domestic or export markets should be encouraged in highly selected areas and commodities. This strategy alone can sustain the production and marketing of organic food on a long-term basis.

Conclusions and Way Forward

India is bestowed with a lot of potential to produce all varieties of organic products due to its various agro-climatic regions and traditional knowledge. Due to low input demand, rainfed areas are potential hotspots to produce organic products (Gopinath *et al.,* 2019). It is evident from research findings that many crops respond better to organic management particularly after an initial conversion period of 2-3 years in rainfed areas. Organic farming can significantly contribute to improving the livelihoods of small holders as it generates higher incomes and involves less risk. As the export potential is increasing, overcoming the hurdles in rainfed areas, developing cost effective production systems, and adequate scientific research will help India emerge as a good exporter of organic products and increase farm net revenues. Some of the thrust areas to promote organic farming in rainfed areas are:

- Delineation of the potential areas/ zones like hill and tribal areas, for rainfed organic farming by identifying contiguous blocks of areas with little or no chemical input use and where productivity can be enhanced by using permitted inputs to enable group certification to farmers.
- Carry out a country wide survey/inventorisation of areas in arid, semi-arid and dry sub humid regions about the level of chemical input use, and productivity in selected commodities which have potential to fetch price premiums in international markets.
- Survey, documentation and critical evaluation of indigenous technological knowledge on organic farming.
- Inter-disciplinary and location-specific research for development of package of practices for organic farming and integrated organic farming systems. Organic production packages will be more location-specific than inorganic package of practices as the input use depends largely on locally available resources.
- Development of cost effective technology for on-farm organic manure production as well as large scale

production of compost from domestic, agricultural, and industrial wastes.

- Generation of adequate scientific information on the yield, quality, economics and post-harvest aspects of various crops under different management levels and agro-climatic conditions.
- Assess the climate change adaptation and mitigation potential of rainfed organic farming systems
- Extension machinery including State departments, NGOs, and other private organizations should develop intensive partnerships, at grassroots and policy levels in promoting organic farming.
- Development of quality standards, and setting up of effective marketing chains to sell organic produce in both domestic and international markets.
- Policy initiatives such as providing incentives to those farmers willing to shift to organic farming, providing market information, and subsidized supply of inputs.

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