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Organic System in Low Rainfall Areas for Climate Resilience and Returns

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Low rainfall areas or arid regions (rainfall below 500 mm/yr) of the country cover about 45 million ha area, mainly in Rajasthan (12 districts) and a small part in Haryana, Gujarat, Andhra Pradesh and Tamil Nadu. Low rainfall also has erratic distribution causing uncertainty and frequent drought. This condition gets further aggravated due to climate change effects. It has been reported that the impact of projected climate change by the end of 21st century is likely to be more pronounced in arid region than semi-arid or sub-humid region of India (Rao *et al* 2009).

Traditionally in such arid regions multi-component farming systems are being followed that includes annuals, perennials and animal component. These traditional organic systems are based on recycling of local resources and helps in mitigating the risk of rainfall uncertainty. Even under climatic uncertainties these systems have sustained since ages albeit with low productivity. Inefficient use of local resources was the main cause for low productivity.

In last few decades, although several attempts have been made to improve productivity of these traditional systems with the use of external inputs like fertilizers, pesticides, weedicides etc, but success was limited only to the good rainfall years, as these inputs performs well under assured water availability. But during below average rainfall years use of synthetic inputs was rather counterproductive. In view of high cost of chemical fertilizers and uncertain crop yield response Agrawal and Venkateshwrlu (1989) suggested to increase the use of organic manure for sustainable production. To mitigate the effect of climate uncertainty, balance nutrition through organic sources is the best viable option.

Evergreen revolution through organic

Stagnating yields, negative impact on environment, soil health and farmers' economy were some of the side effects of green revolution and provided fuel to search new and unexploited areas to ensure increased productivity through eco-friendly or evergreen farming. The low rainfall areas that were fairly untouched from green revolution due to shortage of water deserve specific attention on priority for the future self sustainable - self generating system (Sharma, 2001) with the following components:

1. **Efficient use of limited water:** Water is the scarcest resource of these regions. Use of synthetic fertilizers not only increase water demand of crop but also reduce water holding capacity of already light soils. At many places ground water combined with fertilizers is being used lavishly for production of rice, wheat, cotton and vegetables resulting into severe depletion of ground water and soil fertility. There are emerging possibilities of desertification in these areas. Contrary to chemical intensive farming, it has been found by experiments and experience that use of organic manure increases soil water holding capacity and crop water use efficiency, resulting in decrease in number of irrigation by 2-4 times in food crops. Water use can be further economized by growing low water demanding crops like spices & medicinal plants.

2. **Low fertilizer use - early conversion** : Low fertilizer consumption (48.3 kg/ha compared to national average of 135.2 kg/ha) offers excellent opportunity for early and easy conversion into organic farming. According to the priority areas of National organic farming policy this part of the country comes under the priority I and II.

3. **Diversified farming system** : Farming systems in the region are highly diversified in nature with crops, trees, animals and grasses. This system is scientifically more efficient in nutrient recycling and restoration of soil fertility. Availability of 10-30 trees/ha coupled with 2-5 animals per farm family is the backbone of this integrated farming system which not only minimizes pest incidence but also favours organic farming approach and controls desertification.

4. **Rich traditional wisdom** : Rich traditional wisdom in these areas for restoration of soil fertility and for pest control further strengthen and provide strong infrastructure for organic system (Sharma and Goyal 2000).

5. **Natural Availability of inputs** : Plants like neem, pongamia, calotropis etc are ideal sources of biopesticides and are abundantly available. Neem being available in various densities offers effective pest control in crops of low rainfall areas (Verma and Vir, 1997) under IPM mode. Minerals like rock phosphate, gypsum and lime are also available in large quantity for soil amelioration and nutrient mobilization. Higher dependence of such farming systems on animals is an added advantage for ensuring balanced nutrient supply.

6. **Employment opportunities** : High density as well as high growth of human resource remains underutilized throughout the year due to erratic rainfall and limited irrigation facilities. Migration of human resources during drought hampers development efforts of the state. Since organic farming is labour intensive and input production and availability is managed at local level, there is ample opportunity for employment and proper utilization of human resource.

7. **Soil improvement:** Soils are poor in water holding capacity and deficient in majority of essential nutrients. Addition of organic matter not only improves the water holding capacity but also ensures nutrient supply in a balanced manner.

8. **Mitigating effect of climate change**: Worldwide 90 million tons of mineral oil or natural gases are processed to get Nitrogenous fertilizers every year resulting into 250 million tons of CO_2 emission. On the contrary, organic farms return 575 to 700 kg/ ha CO_2 to the soil. Organic farming approaches, thus reduce CO_2 emission by eliminating synthetic fertilizers, and at the same time reduce atmospheric concentration of this gas by storing it in the soil, a win-win situation (Niggli, 2008). Soils with higher humus content are best equipped to address the adverse effects of climate change.

9. **High value monopoly crops** : These areas have four major export oriented crops namely Cluster bean (as guar gum), Sesame, Cumin and Psyllium (*isabgol*). Total export of these crops is around Rs 2000 crore ($400m) per year. In view of present trend and competitive market, enhancing export of mainly organic produce is a distinct opportunity.

Therefore there are ample opportunities in arid areas for promotion of organic farming.

Adequate availability of organic inputs

Availability of organic inputs in adequate quantities is always questioned and more so in the areas where biomass production is low. To assess the ground reality, a survey was conducted in four districts i.e. Jodhpur, Nagaur, Pali and Barmer during 2006-08. A questionnaire was developed to get primary information from selected blocks. Secondary

data was collected to get information at village and district level. Survey revealed that:

- Availability of biomass at farm level was influenced by several factors like rainfall, cropping pattern, size of holding, availability of labour etc. In general most of the farmers were found to be using raw cow dung, kept under sunlight for months. Manure obtained from this method was generally partly decomposed with low nutrient profile especially nitrogen. On an average 1.5-4.5 t/ha of such organic manure was available at farm level in the form of crop residues and animal dung.
- Availability was 1.5-2.0 folds higher at village level with farmers having cattle for dairy purpose. High availability of unproductive and old animals in many villages was also an opportunity for increased biomass availability for manuring purpose. Such cattle were found to be providing 4.6 to 11 kg of nitrogen per ha per year through urine (calculation based on total agriculture land divided by total number of animals in the village).
- Trees are integral part of farming systems of arid zone and contribute equivalent to 0.04t manure/tree. Trees growing in common land, protected areas, waste land etc also contribute to organic input availability.
- Availability was found to be further increased at district level, as intensive dairy farming is prevalent in peri-urban areas.
- Pooling of organic input availability from all the sources revealed that 4.5-5.0 tons of biomass is readily available for farming purpose.
- The availability of nutrient can be further increased by adopting following management practices-
    1. Crop rotation with leguminous crops like cluster bean, moth bean, moong bean etc.
    2. Avoiding heaping of dung under sun and use of improved methods of composting. In arid zone due to shortage of water and high temperature pit composting method has been found most suitable.
    3. Tree leaf litter, animal urine, bones of dead animals, non palatable weed biomass are some of the other rich and under utilized sources of nutrients.

Model organic farm (MOF) at CAZRI

Considering the possibilities and to explore the potential through experimentation on organic production system for low rainfall areas, a 2.0 ha model organic farm was established during 2008, within the Central Research Farm CAZRI, Jodhpur with the partial financial support of the National Centre of Organic Farming, Ghaziabad. The farm was registered for certification and got the status of "Certified Organic Farm" in the year 2011. Following core facilities were created at the MOF to develop environment for research on organic system-

1. A trench cum mound was made around the farm for *in-situ* conservation of rainwater and to avoid drift of contamination through water from adjoining fields. *Cassia angustifola,* a medicinal shrub was planted on the mound for round the year availability of flower for predators and further filtration of contamination.
2. Two rainwater harvesting tanks of 5000 litres capacity (each) were constructed in the model organic farm. Cemented catchments area was made around each pond for maximum collection of rainwater. This catchment area was also utilized for drying and thrashing of crops during the lean period. The rain water so collected was used for raising low volume-high value crops like cumin, psyllium etc.
3. Manual weeding was done regularly and uprooted weed were spread in the same field as mulch that got decomposed in

due course and contributed 1.5-2.0 t/ha of organic matter

4. Biodiversity plantation was also done, that includes fruit trees namely *Ziziphus mauritiana, Phyllanthus emblica, Cordia mixa* and shrubs e.g. henna (*Lawsonia alba)* for shelter to predators, and *Adathoda vasica, Vitex nigundo, Aloe vera* and *Casia angustifolia* for botanical pesticides. Besides these, naturally grown, 32 plants of Khejri (*Prosopis cineraria,* a climax MPTS of the region) and 2 plants of neem (*Azadirachta indica)* were also protected. This plantation ensured adequate nectar supply and shelter to the beneficial insects. Neem plantation was done around the field for preparation of botanical pestcides.
5. The farm was registered with Rajasthan Organic Certification Agency (ROCA), Jaipur for organic certification and entire process as per the requirement of National Programme of Organic Production (NPOP) was followed to ensure organic integrity at all stages of cultivation and experimentation.
6. Six compost pits were made at one corner of the farm for making compost from the MOF generated crop waste.
7. Botanical pesticides were prepared with leaves of neem, calotropis, adhathoda etc and neem cake.
8. Pheromone traps were installed for trapping the pests like while grub, moth etc.
9. All the implements and produce of the MOF were kept in the store, inside the field boundary to avoid any contamination.
10. Display of useful information at various places was available in the field for the benefit of visitors.
11. The design of the farm was based on three principles of sustainability i.e. conservation of rain water, efficient use of field waste and proper field education (for the users).

Research outcome

A rotation of four crops including cluster bean and sesame in rainy season (kharif) and cumin and psyllium in winter (rabi) was selected for the study. On the basis of experiments conducted at MOF the findings are as follows:

Contribution of manures and legumes – Yields were found to be increasing, significantly with the increase in use of organic manures from 2.5 to 7.5 tons/ha in all the crops. Legume cultivation in kharif season, on an average contributed to 25-30% increase in yield in the subsequent crops of cumin and psyllium (Table 1).

Improvement in soil properties - Increase in soil moisture retention with the use of organic manure was observed (Fig 1) that helped in better growth and yield of crops. Similarly increase in soil organic carbon from 0.23% to 0.29% was recorded after three year application of compost @ 5.0t/ha.

Crop resilience to rainfall variability - Crop resilience to climatic variability was enhanced with the use of organic manure as is evident from the two year data. Since crop yield is the ultimate product of all the interactions, therefore only yield comparison is given here.

1. During 2009 because of low (208mm) as well as highly erratic rainfall (only 4 good rainy days and 2 long dry spell of 17 and 29 days), crop faced drought conditions. The severity was further increased by dry-hot winds during milking stage of crop in September. With this set of conditions while crops in the conventional plots were failed, but the crop grown with organic inputs coupled with timely interculture for moisture conservation could yielded up to 30-40% of the average yields. A yield of 196.3 kg/ha of sesame and 206.8 kg/ha of cluster bean was obtained in sampled plots (Table 2).

Table 1. Effect of rotation and level of manuring on the yield of rabi crops (irrigated with harvested rainwater under organic management (manuring was done to Kharif crops)

Crop sequence	Yield of crop(kg/ha)					
	Cumin			Psyllium		
	Manure application(t/ha)			Manure application(t/ha)		
	0.0	2.5	5.0	0.0	2.5	5.0
After sesame	229.4	374.3	459.8	424.7	578.8	672.9
After cluster bean	407.9	489.3	516.4	629.4	786.2	808.3

Fig. 1 Soil moisture status in sesame and cluster bean plots.

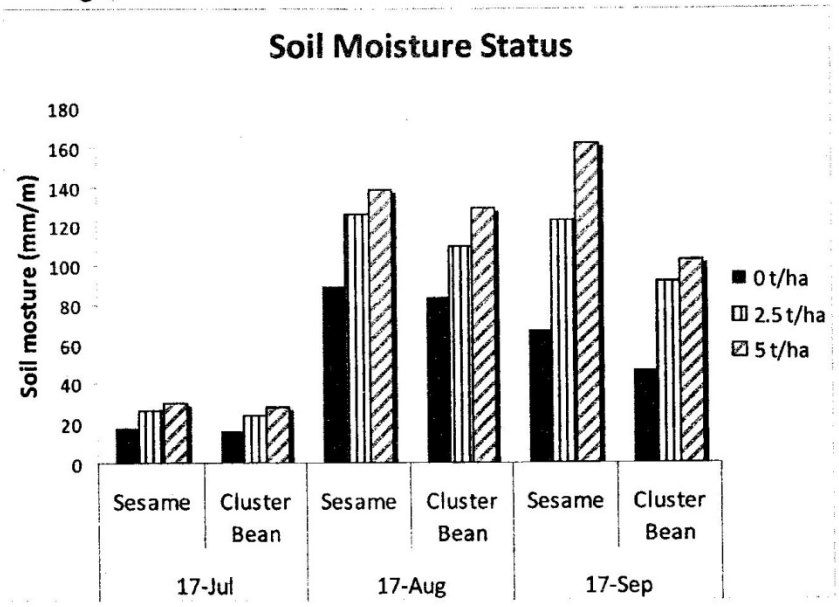

Table 2. Crop resilience to climatic variability (average rainfall at experimental site was 366mm/yr)

Year and rainfall	Crop yield (Kg/ha)			
	Sesame		Cluster bean	
	Organic	Conventional	Organic	Conventional
2009 (rainfall 208 mm)	196.3	0.0	206.8	0.0
2010 (rainfall 460mm)	886.6	523.9	630.2	308.6

2. In 2010, above normal rainfall (460 mm) during the cropping season was recorded. Under such situations organic plots due to organic matter incorporation maintained optimum aeration & moisture in soil, resulted in good crop growth while in the conventional plots crop growth was stunted, and produced poor yield (Table 2).

Pest Management : Pests were kept below economic threshold level with the integrated use of following eco-technologies:

- Soil application of neem seed powder @ 300 kg/ha
- Use of well prepared compost @ 5.0 t/ha
- *Trichoderma viride* application in soil and as seed treatment
- Use of healthy seed and also free from weed seeds
- Hand weeding and mulching

- Prophylactic spray of neem seed kernel extract solution (5.0%) at regular interval
- Use of pheromone traps according to the pest
- Regular visit of every part of the field to assess crop health conditions and timely spray was done at the initial stage of pest attack.

Observations in pest control - In organic farming every aspect/ effect cannot be quantified because of limitations in experimental designs. Therefore, some of the following results are based on visual yet continuous observations that were compared with the conventional farming plots-

1. Neem seed kernel extract (NSKE) spray either as prophylactic or at initial stage of pest attack was found very effective.
2. Neem seed powder was found to be effective in controlling soil pest like termite and white grub.
3. Aphids in cumin and psyllium were effectively controlled by lady bird beetle and some other predators.
4. Birds played a great role in controlling pest both at larval and adult stage.

Crop yield comparison - There are general apprehensions that organic system is poor yielder. However, findings at MOF, CAZRI shows that, at initial developmental stage of organic system there may be reduction in yield but after 2-3 years, once the system developed, the yield levels were comparable to the conventional (chemical input based) system. At third year yield of sesame 886.6 kg/ha, cluster bean 630.2 kg/ha, cumin 516.9 kg/ha and psyllium 808.4 kg/ha was recorded (Table 3). This was comparable to the average yield of conventional system. As mentioned earlier 2009 was a drought year therefore, data could not follow the trend however, organic performed much better then their conventional counterpart (Table 3).

Partitioning of sink : In a separate experiment on pearl millet (staple food of low rainfall areas) it was observed that, as the manure level increased, percentage of sink to grain increased from 15.7 to 19.8% while it decreased in case of stem and leaf (Table 4). This shows better partitioning of sink that increased grain yield, with the application of manure. It may be due to balanced nutrition through compost that used by plant for grain formation

Economics - Organic system took three year for development. Once the system developed most of the inputs e.g. seed, manure, bio-pesticides etc. were made with local resources, therefore major cost of cultivation became negligible and major expenditure was on the labor work for seeding, weeding, spraying, harvesting etc. Benefit : Cost ratio of 1.79, 3.06 and 2.74 was obtained with the application of manure @ 0.0 t/ha, 2.5 t/ha and 5.0 t/ha. However, highest profit of Rs. 27996.05/- per ha was obtained with the application of 5.0 t/ha manure. This shows that if there is limitation of manure, application of 2.5 t/ha manure is recommended. Although profitability will increase up to 5.0 t/ha manure application (if available).

Table 3. Yield comparison of organic with conventional system

Year	Crop yield (kg/ha)							
	Sesame (rainfed)		Cluster bean (rainfed)		Cumin (irrigated with harvested rainwater)		Psyllium (irrigated with harvested rainwater)	
	ORG	CON	ORG	CON	ORG	CON	ORG	CON
Ist year (2008)	343.9	467.3	476.3	493.9	323.3	496.3	382.3	523.9
IInd year (2009)	196.3	0.0*	206.8	0.0*	423.9	496.3	485.7	510.7
IIIrd year (2010)	886.6	523.9	630.2	308.6	516.6	497.2	808.4	786.3

ORG= Organic ,CON= conventional, *Crop failed due to drought

Table 4: Partitioning of sink in pearl millet

Level of manure (t/ha)	Yield of plant part (g /m^2)				Total biological yield (g /m^2)
	Root	Stem	Leaf	Grain	
0.0	173.8 (25.1)	152.6 (22.0)	257.2 (37.2)	109.3 (15.7)	691.8
2.5	546.9 (27.7)	395.2 (20.7)	658.9 (34.2)	352.6 (18.0)	1951.6
5.0	692.8 (27.8)	429.6 (16.6)	908.4 (35.8)	501.3 (19.8)	2530.7

Figure in parenthesis is the percentage of total biological yield

Suggestions for promotion of organic farming in low rainfall areas

- Priority needs to be given to organic farming in ongoing programs like all rural development programs, watershed development programs, SGSY, RKVY, MNREGA, Food security mission and Horticulture mission etc.
- Popularization of organic farming for sustainability while keeping certification optional.
- Dissemination of organic farming in a holistic manner by all the technical and funding agencies
- Encouragement of decentralized input supply must be given priority for quality, savings in cost and efficient utilization of local resources.
- Adoption of improved methods of composting, as it is one of the major factor that improves nutrient availability
- Awareness and capacity building programs need to be intensified
- Provision of subsidy may be made for organic inputs to make organic produce more competitive.
- Promotion of high value crops e.g. spices, medicinal plants etc. that requires less water but fetches more prices
- Research is being done on various components of organic farming by ICAR/SAUs, yet more research is needed to integrate the efforts and assess their effects.

Conclusion

In water scarcity and light soils areas, organic approaches are most suitable for sustainable and profitable farming. Organic production in such areas not only boosts the economy of region but also sustain the productivity with natural resources. Some monopoly high value crops of this region like seed spices are having great international demand if produced organically. The need is to do research on development of easy & economic technologies, development of processing and marketing infrastructure and financial well as technical support for quality organic production.

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