National Innovation in Climate Resilient Agriculture – A Case Study at Bangalore Rural district of Karnataka

ABSTRACT

Drought is a predominant cause of lower yield world-wide. In arid and semi-arid tracts that include Eastern Dry-Zone of Karnataka, drought is the major climatic vulnerability Associated with reduced rainy days, increased rainfall intensity and intermittent dry spells. Improved agricultural practices, *viz*. selection of appropriate varieties, method of crop establishment, *in-situ* moisture conservation, ex-situ rainwater harvesting and its efficient utilization and real time agro advisory services were demonstrated in Chikkamaranahalli cluster, Bengaluru Rural district of Karnataka during2011 to 2019. Among finger millet varieties, long duration (MR-1) for July sowing, medium duration (GPU-28) for August first fortnight sowing and short duration (GPU-48) for August second fortnight sowing performed better. *In-situ* moisture conservation through moisture conservation furrows between paired rows of pigeonpea under finger millet + pigeon pea (8:2) and groundnut + pigeon pea (8:2) intercropping recorded significantly higher yield compared to farmer's practice. Establishment of finger millet through transplanting and direct sowing using modified bullock drawn seed drill recorded higher yield compared to conventional broadcasting method. Real time agro advisory services helped for decision-making on timeliness of operation. The climate resilient practices helped in bringing sustainability under vagaries of monsoon.

Keywords: Climate resilient practices, In-situ moisture conservation, Real time agro advisory, sustainability

1. INTRODUCTION

Rainfed agriculture occupies a prominent place in Indian economy and rural livelihoods. In India, agriculture is the source of livelihood for nearly two-thirds of the population. Of the 141 m ha of net sown area in the country, 80 m ha is rainfed and will remain so at least for a foreseeable future (Srinivasa Rao *et al*., 2013). The impact of climate change and variability in the country on agricultural production is quite evident in the recent years. Climate change threatens the sustainability of modern day agriculture. Constantly changing climatic conditions around the world demand constant efforts to understand and adapt to environmental challenges for sustainable crop production.

Among the various factors affecting the agricultural production, weather is the most important one. Every phase of growth and development in plant is affected by weather. Among the weather parameters, rainfall and its distribution fluctuates greatly than other parameters. Any variability in the rainfall during the crop season, such as delay in onset of monsoon, excessive rains and prolonged dry spells would affect the crop growth and finally the quality and quantity of the produce. Adoption of real time contingencies in crop management based on weather forecasts can minimize crop losses (Ramachandrappa *et al*., 2018).

Change in climate is likely to aggravate the problems of future food security by exerting pressure on agriculture. India is more vulnerable to climate change in view of higher agriculture dependent population, excessive pressure on natural resources and poor coping mechanisms. In India, significant negative impacts have been implied with medium-term (2010-2039) climate change, predicted to reduce yields by 4.5 to 9 %, which is roughly up to 1.5 % of GDP per year (Jasna *et al*., 2014).

National Initiative on Climate Resilient Agriculture (NICRA) of the ICAR is focusing on the complex challenges like multiple abiotic stresses on crops and livestock, shortage of water, land degradation and loss of biodiversity on a long term basis. The scheme attempts to develop and promote climate resilient technologies in agriculture which will address vulnerable areas of the country. The project focuses on: strategic research to address long-term climate change; demonstration of innovative and risk management technologies in different parts of the country; funding competitive research and capacity building of different stake holders for greater awareness and community action. As the small holder farmers are most vulnerable to climate change, an affordable and effective National Insurance Scheme is being implemented to cover the risk and the related miseries. Similarly, price support system and marketing infrastructure will cover price related risks of the farmer (Panjab Singh, 2016). Climate change impacts all sectors of human life. Agriculture is particularly vulnerable to it. Increased temperature upon climate change may reduce yield of many crops and encourages proliferation of weeds and pests. The overall impact of climate change on agriculture is likely negative. Climate change will have a negative effect on yield of crops across regions, both due to increase in temperature and changes in availability of water. The Government of India has accorded high priority to research and development to cope with climate change in agriculture sector. The Prime Minister's National Action Plan on Climate Change has identified agriculture as one of the eight national missions. With this background, ICAR launched a major project 'National Initiative on Climate Resilient Agriculture' (NICRA) during XI Plan in February 2011. The main objective of the project was to enhance climate resilience through strategic research, technology demonstration and capacity building.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

Adaptation refers to 'adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts' (Smit *et al*., 2000).

National innovation in climate resilient agriculture (NICRA):

The studies on climate change in India and abroad suggest possibilities of making Indian agriculture resilient through adaptation and mitigation measures. Thus, Government of India accorded high research and development priority towards climate resilient agriculture (CRA) and also identified agriculture as one of the eight national missions under prime Minister's National Action Plan on Climate Change (NAPCC). The Government through ICAR launched megaproject "National Initiatives on Climate Resilient Agriculture (NICRA) during 2010-11 for the XI Plan. The project aims at enhancing resilience of Indian agriculture to climate change and its variability through strategic research on adaptation and mitigation measures, their refinement and validation for local and regional needs; and extensive demonstration in dynamic mode. The strategic research component aims at assessing the vulnerability of major agro-ecosystems, monitoring GHG emissions, pest dynamics, pest/pathogen-crop relationship; develop tolerant breed/ varieties; evolve adaptation and mitigation options for climate change regulated on crops, livestock and real-time contingencies at leading ICAR research institutes in a network mode.

"National Innovations in Climate Resilient Agriculture (NICRA)" funded by ICAR-Central Research Institute for Dryland Agriculture (CRIDA) is in operation at Chikkamaranahalli cluster (Chikkamaranahalli, Chikkamaranahalli colony, Chikkaputtayyanapalya, Mudalapalya and Hosapalya), Nelamangala Taluk, Bengaluru Rural district since 2011. Participatory trials were conducted on farmers field from 2011-12 to till date. Fields were selected based on the willingness of farmers to engage in participatory research to evaluate the science based strategy. The socio economic study indicated that, majority of the farmers in the study village are marginal and small farmers and are practicing traditional cropping.

Mono-cropping of finger millet, imbalanced fertilizer use, delayed onset of monsoon, intermittent dry spells, lack of awareness about improved varieties and dryland production practices are the major constraints in crop production, as per PRA and bench mark survey. Based on the farmer's needs, technical interventions have been taken up under different themes. The result of case study has shown possibilities of resources conservation, sustainable production, and livelihood security of farmers.

Rainfall pattern at experimental sites:
The area receives normal rainfall of 750 mm and distribution is highly erratic. The prime objective of the project is to minimize the risk of rainfed crop production through implementation of real time contingency practices in relation to prevailing climatic situations. Before conducting the demonstration, list of farmers was prepared from group meeting and specific skill training was given to the selected farmers. Selected farmers participated in each and every research intervention from soil sampling to harvest. Timely sowing, maintenance of required spacing and plant population, timely weeding and plant protection measures were attended as per the instructions of scientists and a control treatment of farmers' practice was included for comparison. Based on the PRA and benchmark survey, technical interventions have been taken up under different themes to address the climate vulnerability through suitable interventions in project area. The climate resilient agriculture practices, *viz*., selection of crops and cropping systems, improved varieties, rainwater harvesting and timely agriculture operations through farm mechanization were demonstrated. Major soils in the domain area are sandy loam to sandy clay loam with acidic to neutral reaction (pH 4.3 to 6.5). Bimodal rainfall prevailed in the domain with peaks during May and Sept – Oct. The cluster receives a normal annual rainfall of 750 mm (Figure 1) and its major share during Kharif season. Data were converted in to quantitative form and finally per cent increase in yield, technology gap and extension gap and benefit-cost ratio were calculated by using the formula given by Samui *et al*. (2000)

Per cent increase in yield $= \frac{(\text{Grain yield under improved practice} - \text{Grain yield under farmers practice})}{\text{Grain yield under farmers practice}} \times 100$

Technology gap = Potential crop yield - Crop yield under demonstration

Extension gap = Crop yield- under demonstration – Crop yield under farmers' practice

The maximum yield of crop obtained at the research station with favorable weather and crop management practices were accounted as potential yield. While, the maximum yield noticed in the farmers' field during the demonstration is counted for demonstration yield.

The SYI of different intercropping systems was calculated following the equation suggested by Sharma *et al*., 2004

Sustainability yield index (SYI) $= \frac{(\text{A} - \text{SD})}{\text{Ymax}}$

Where, A = Average yield over the years for a particular treatment

SD = Standard deviation for the treatment

Ymax. = Maximum yield obtained of the treatment over the years.

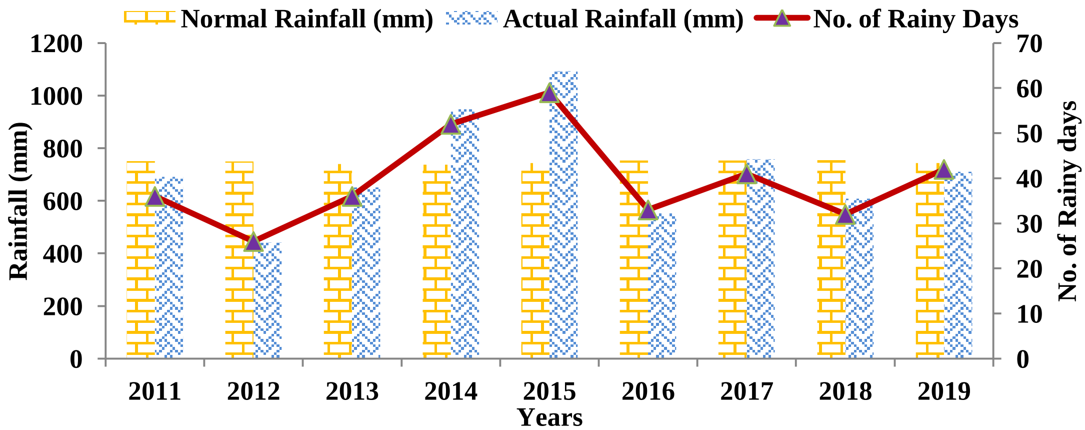

Fig.1: Normal v/s Actual Rainfall during the study period

High yielding finger millet varieties: Wide array of finger millet varieties with different duration and season has been developed and released for cultivation (Table 2). But farmers still are growing long/ medium/ short duration finger millet varieties irrespective of the sowing time and reaping poor yield. Long duration (120-125 days) MR-1 for July sowing, medium duration (110-115 days) GPU-28 for August 1st fortnight sowing and short duration (100-105 days) GPU-48 for August 2nd fortnight sowing.

Method of establishment in finger millet: Considering the tolerance of finger millet for transplanting shock, seedlings were raised in the nursery and transplanted to the main field at an age of 20-25 days as a contingency for delayed onset of monsoon was demonstrated during 2011-2012 to 2019-2020. Direct sowing of same variety was taken up as control simultaneously.

In situ moisture conservation through conservation furrow

Presently, farmers follow Akkadi cropping (mixed cropping) system, *i.e*., 10-14 rows of finger millet or groundnut with one row of mixture of 5-9 crops like fodder sorghum, castor, mustard, sesame, cowpea, pigeon pea, field bean etc. Inter-plant competition and staggered maturity of crops pose yield decline besides posing difficult to harvest. Under the improved practice, simultaneous sowing of groundnut or finger millet with pigeonpea in 8:2 row proportions with 60 cm spacing between the paired rows of pigeonpea and opening of conservation furrow between the paired rows of pigeonpea after 25-30 days after sowing was adopted as a strategy for soil and moisture conservation

Pulse based cropping system:

Simultaneous sowing of pigeonpea and field bean/cowpea in 1:1 row ratio at 90 cm × 22.5 cm and a short duration photo-insensitive field bean / cowpea in 1:1 row proportion (additive series). Maintaining three feet distance between the rows of pigeonpea without losing the main crop. As pigeonpea is a long duration crop and slow growing in early stages, growing of field bean/cowpea as additive series increases the land use productivity.

Modified seed drill for finger millet sowing: The farmers in the domain used to sow finger millet either by broadcasting or by drilling with local seed drill. Further, local seed drill is heavy necessitating three laborers for managing bullock and dropping the seeds. Also, it is closely spaced and difficult to carry inter-cultivation posing a severe weed menace. Considering the above difficulties, a light weight, 30 cm row spaced seed drill was designed for the convenience of sowing with less labour (2 No.) and facilitating inter cultivation.

Recharging of borewell in filter bed system: During kharif 2012-14, the experiment was set up under NICRA project at Hosapalya, Nelamangala Taluk, Bengaluru rural district to record the impact of recharging by feeding the runoff water to the failed low yielding borewell with filter bed. A pit of 3m × 3m × 2.9m dimension was excavated in the region centering the casing of the borewell. At the bottom of the pit, filter holes were made to a casing pipe and mosquito mesh was fixed tightly such that the casing pipe will function as a filter (Ramachandrappa *et al*., 2013). Then different layers of filter bed system were laid as per the following specification and diagrammatically indicated in Figure 2. The runoff water from the catchment was diverted to the pit for artificial recharging. The rainfall and runoff events were recorded in the respective locations adopting standard procedure. After completing the filling of filter bed recharge pit, observation on borewell yield was recorded at 15 days interval by collecting water in a measuring tub per unit time and the discharge was calculated by adopting standard procedure outlined by Michael and Ojha (2014).

Agromet- Advisory Services and Crop-Weather Bulletins: are issued twice a week (Tuesdays and Fridays) in collaboration with AICRPAM and IMD and messages are written in front of milk collection centers of Chikkaputtayanapalya and Hosapalya for the benefit of project farmers and surrounding villages. The information on rainfall, cloudy weather and dryspell was effectively used for sowing, spraying and harvesting operations and was helpful in reducing the loss. For assessing the impacts of agro-met advisory services, the farmers using the agro-met advisory services were selected. A questionnaire including climatic anomalies largely influencing crop production, source and frequency of weather forecast received by the farmers, features and qualities of agro advisory bulletins and willingness of the farmers to pay for the services, was prepared. Sample survey was conducted and 35 farmers were interviewed. The study area consisted of NICRA adopted villages in Chikkamaranahalli Cluster, Nelamangala taluk Bangalore Rural District.

3. RESULTS AND DISCUSSION

Finger millet varieties for different sowing window

Regular onset of monsoon was observed during the study period (2011-19) except during 2012 and 2017 which resulted in higher grain yield, net returns and B:C ratio with long duration finger millet variety (MR-1) sown during July. Delayed onset of monsoon during 2012 and 2017, the agro-advisory suggested the farmers to adopt a medium duration variety (GPU- 28) for late sowing in August. Farmers adopting the medium duration variety (GPU-28) realized an average higher grain yield of 1992 kg/ha, compared to the long duration variety (MR-1,1782 kg/ha). Delayed sowing of long duration variety pose end-season moisture stress on plants and arrested under low temperature during flowering and results in decreased yield. In a situation with normal onset of monsoon, direct sowing of finger millet variety MR-1 was found to be more profitable than direct sowing of GPU-28 (Hegde and Jayarama Reddy, 1983).

Transplanting of finger millet:

Finger millet tolerates transplanting shock and works as a strategy for delayed onset of monsoon. Transplanting of finger millet recorded significantly higher average finger millet grain yield (2442 kg/ha) and SYI (0.90) over the years compared to direct sowing (2091 kg/ha and 0.76 respectively). Maintenance of optimum plant population, timeliness in flowering and maturity are the causes for higher yield (Ramachandrappa *et al*., 2013).

Moisture conservation furrow:

Opening of moisture conservation furrow between paired rows of pigeonpea in finger millet + pigeonpea (8:2) intercropping system recorded higher average finger millet grain equivalent yield of 2714 kg/ha, higher net returns of 41689 /ha and B: C ratio of 2.60 as compared to farmers' practice (Table 3). The average additional equivalent yield under improved technology was 898 kg/ha which is 49.4 % higher over farmers practice. The additional net return recorded was 22,705 /ha. Finger millet + pigeonpea (8:2) intercropping system recorded higher value of sustainable yield index (0.76) over farmer's practice (0.35). The technology gap was 2.86 q/ha. Technology gap implies researchable issues for realization of potential yield while extension gap implies what can be achieved by the transfer of existing technology. The increased yield and net returns accrued were associated with increased soil profile moisture as a result of conservation furrow. Besides, inter-cropping of compatible crops benefit mutually in improving system productivity and returns. Pigeonpea being a leguminous crop helps for biological nitrogen fixation fulfilling the nitrogen needs of finger millet partly.

Groundnut + Pigeonpea (8:2) Intercropping System for Higher Productivity

Groundnut + pigeonpea (8:2) intercropping system with a moisture conservation furrow between paired rows of pigeonpea recorded higher average groundnut equivalent yield (1640 kg/ ha) and economic returns (24,960 /ha), B:C ratio (2.19) compared to farmers' practice (Table 4). The average additional equivalent yield under improved technologies over farmers' practice was 624 kg/ha, which is 61.4% higher over farmers' practice. Higher value of sustainable yield index was recorded for 8:2 groundnut + pigeonpea (0.73) over farmers' practice (0.35). The technology gap of 3.60 q/ha and extension gap of 6.24 q/ha. The advantage of having conservation furrow between two rows of pigeonpea in groundnut + pigeonpea (8:2) intercropping has been reported by Ramachandrappa *et al*. (2011). These results were in conformity with the findings of Badanur *et al*. (1995), Arjun Prasad and Ratan Singh (1998), Raikwar and Srivastva (2013) and Vijay Kumar *et al*. (2014).

Pigeonpea + Fieldbean (1:1) Intercropping System

Introduction of pigeonpea + field bean (1:1) intercropping system resulted in higher pigeonpea average grain equivalent yield (1047 kg/ha), returns (20472 /ha) and B: C ratio (1.68) compared to sole crop of pigeonpea (608 kg/ha, 9145 /ha and 1.22, respectively, Table 5). The value of sustainability yield index recorded for pigeonpea + field bean (0.81) was higher compared to farmer's practice of growing pigeonpea as sole crop (0.39). Ramachandrappa et al. (2014 and 2015) also reported similar results.

Modified Bullock Drawn Seeddrill for Finger millet

Finger millet crop sown using modified bullock drawn seed drill recorded average higher grain yield (2281 kg/ha), net returns (37426/ha) and B:C ratio (2.50) as compared to farmer's practice (1829 kg/ha, 249928/ha and 1.50, respectively). The modified seed drill facilitated optimum plant population, ease of inter-cultivation and helped in achieving higher yield (Table 6). These results are in accordance with Ramachandrappa *et al*. (2011, 2014 and 2016).

Recharging of Borewell in Filter Bed System:

The discharge rate of a borewell with filter bed during 2012-13, was on an average of 8.87 lpm. After implementing recharge treatment, over the year discharge rate of bore well with filter bed was 9.7 ltr. min^{-1} and in the rainy season, the average discharge rate was

10.87 lpm while 8.1 lpm in summer season. The discharge rate was increased with the advancement of monsoon and declined towards its cessession.

Agromet Advisory Services

Weather forecast and weather based agromet advisories help in increasing the economic benefit to the farmers by suggesting them the suitable management practices according to the weather conditions. Hence, study was, undertaken on adaptation of agromet advisory bulletin and economic impact of agromet advisory services. The economic impact studies indicated that there was considerable benefit to farmers who adopted the agromet advisories. The per cent gain in yield due to adoption of suggested contingency cropping systems ranged from 15.8 to 72.3 over traditional cropping systems. The yield increase in cropping systems *viz*., finger millet + pigeonpea, groundnut + pigeonpea, and pigeonpea + field bean was to the tune of 898, 624 and 435 kg ha-1, respectively. Transplanting of finger millet registered higher yield as contingency measure. Raje gowda *et al*. (2008) and Ramachandrappa *et al*. (2018) reported similar results that, in the eastern dry zone of Karnataka the farmers who have adopted the agromet advisories have realized additional benefit. Hence, it can be seen that the agro advisory information communicated to farmers in NICRA villages was useful to the farmers. Majority of farmers who followed the weather related agromet advisories were able to reduce the crop losses.

Table 1: Yield and economics of different finger millet varieties (mean of 2011-2019)

Year	Grain yield (kg/ha)	Net Returns (₹/ ha)	B:C ratio
MR-1 (Long duration)	2224	32226	2.38
GPU-28 (Medium duration)	2081	29810	2.28
GPU-48 (Short duration)	2338	45330	2.68

Table 2: Performance of finger millet under different establishment methods

Method of establishment	Grain yield (kg/ha)	Net Returns (/ ha)	B:C ratio	SYI	Percent increase in yield	Technology gap	Extension gap
Transplanting	2422	35352	2.52	0.90	15.8	578.4	330.6
Direct sown	2091	29130	2.31	0.76	-	909.0	-

Table 3: Yield (kg/ha) and economics (/ ha) of finger millet + pigeonpea (8:2) cropping system (Mean of 2011-2019)

Treatment	Finger millet equivalent Yield (kg/ha)	Net Returns (/ ha)	B:C ratio	SYI	% increase in yield	Technology gap	Extension gap
Improved practice	2714	41689	2.6	0.76	49.4	286	898
Farmer's practice	1816	18984	1.7	0.43	-	1184	-

Table 4: Yield (kg/ha) and economics (/ ha) of groundnut + pigeonpea (8:2) cropping system (mean of 9 years)

Treatment	Groundnut equivalent Yield (kg/ha)	Net Returns (/ ha)	B:C ratio	SYI	Percent increase in yield	Technology gap	Extension gap
Improved practice	1640	44359	2.3	0.73	61.4	360	624
Farmers practice	1016	4843	1.2	0.35	-	984	-

Table 5: Yield (kg/ha) and economics (/ ha) in pulse based production system (mean of 9 years)

Treatment	Pigeonpea equivalent Yield (kg/ha)	Net Returns (/ ha)	B:C ratio	SYI	Percent increase in yield	Technology gap	Extension gap
Pigeonpea + cowpea	965	32820	2.07	0.73	58.7	235.2	356.9
Pigeonpea + field bean	1047	40733	2.32	0.81	72.3	152.8	439.4
Sole pigeonpea	608	13711	1.47	0.39	-	592.1	-

Table 6: Benefit of modified bullock drawn seed drill for sowing of finger millet

Treatment	Finger millet Yield (kg/ha)	Net Returns (/ ha)	B:C ratio	SYI	% increase in yield	Technology gap	Extension gap
With improved implement	2162	34161	2.43	0.87	20.8	755	193
Without improved implement	1773	17738	1.72	0.82	-	1141	-

Table 7: Impact of agro advisory services on productivity and economics of cropping systems (mean of 9 years)

Crops/ cropping system	AAS farmers			Non AAS farmers			Additional income to AAS farmers	% gain in yield over Non AAS farmers
	Yield (kg/ha)	Returns (Rs./ha)	B: C ratio	Yield (kg/ha)	Returns (Rs./ha)	B: C ratio		
Transplanting of finger millet	2422	35352	2.52	2091	29130	2.31	6222	15.8
Finger millet + pigeonpea (8:2)	2714	41689	2.6	1816	18984	1.7	22705	49.4
Pigeonpea + cowpea (1:1)	965	32820	2.07	608	13711	1.47	19109	58.7
Pigeonpea + field bean (1:1)	1047	40733	2.32	608	13711	1.47	27022	72.3

4. CONCLUSION

Sustainable dryland practices *viz*., moisture conservation furrow in finger millet + pigeonpea (8:2) and groundnut + pigeonpea (8:2) intercropping, intercropping of pigeonpea + field bean (1:1), adoption of improved varieties of fingermillet according to the sowing window, INM in fingermillet proved superior in improving productivity and over the year of its existence, agro advisory services had established sufficient credibility and reliability among the farming community. The farmers adopted the free advice given through the service and also realized benefits, hence improving the livelihood of dryland farmers.

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