**Cotton and Soybean based Risk Resilient Intercropping Systems for Rainfed Black Soils of Akola District of Maharashtra, India**

.

ABSTRACT

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| --- |
| The National Initiative on Climate Resilient Agriculture Project (NICRA) of AICRP for Dryland Agriculture, Dr. PDKV, Akola is implemented with study, analyze and popularize risk resilient rain fed intercropping systems in black soils of Akola district to mitigate climate vulnerability. Keeping this point in view, the assessment studies on different intercropping systems along with their respective sole crops were implemented as technology demonstrations in a participatory demonstration and action research mode with active participation of farmers in Warkhed and Kajleshwar village of Barshitakli Taluka of Akola district of Maharashtra during the year 2021-22 to 2023-24 as a part of the study. The intercropping system of soybean + pigeonpea (4:2) has given significantly higher soybean equivalent yield (2040 kg ha-1), net monetary returns (Rs.80891/- ha-1) and B:C ratio (3.65). Soybean + piegeonpea (6:1) also significantly enhance the soybean equivalent yield which was 1829 kg ha-1 and B:C ratio of 3.03 which was higher than sole soybean i.e 1415 kg ha-1 with B:C ratio of 2.59. Cotton + greengram (1:1) recorded higher cotton equivalent yield (2116 Kg ha-1), net monetary returns (Rs.95399/- ha-1), B:C ratio (2.82) and rainwater use efficiency (2.58) over sole cotton which has recorded yield of 1645 Kg ha-1, net monetary returns (Rs.74035/- ha-1), B:C ratio (2.57) and rainwater use efficiency (2.03). In Akola district of Maharashtra soybean + pigeonpea (4:2) and cotton + greengram (1:1) were identified as the best risk resilient intercropping systems that would help provide sustainable crop production in rain fed regions. |

*Keywords: NICRA, Rain fed, Intercropping systems, Equivalent yield*

1. INTRODUCTION

About 60% of total cultivated area in India is managed rain fed ecosystem, wherein crop production is dependent on rainfall. India ranks first among the rainfed agricultural countries of the world in terms of both extent and value of produce. Rain fed agriculture supports 40% of the national food demands (Thimmegowda *et al*., 2016). Rain fed agriculture occupies 67% net sown area, contributing 44% of food grains and supporting 40% of the population. The vulnerability of the rainfed regions is associated with low and erratic rainfall, land degradation, poor productivity, low level of input use and technology adoption, low draft power availability (Mayande and Katyal, 1996), inadequate fodder availability low productive livestock and resource poor farmers and inadequate credit availability. These areas receive an annual rainfall between 700 -1000 mm, which is unevenly distributed. As a result, a significant fall in food production is often noticed. The Rain fed agriculture as such is most impacted by climate change (Asha latha *et al*., 2012). Added to this, reduced number of rainy days and increased rainfall intensity resulting in heavy crop losses need serious attention to bring stability of rain fed ecosystems. Therefore, it is of utmost importance to enhance resilience of rain fed agriculture to climate change through planned adaptation of appropriate cropping systems and also with other management practices of natural resource management (Singh *et al.,* 2004).

Hence, information on land use/land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare (Patode *et al*., 2017). The water resources management plan ensures judicious and effective use of water resources in the micro watershed, enhancing productivity and mitigating drought. It identifies potential sites for surface water development and groundwater exploitation, reflecting a careful approach to sustainable resource use (Ramamohan Reddy *et al*., 2013; Patode *et al*., 2016).

Intercropping systems involve two or more crop species or genotypes grown together and coexisting for a time. This latter criterion distinguishes intercropping from mixed monocropping and rotation cropping (Vandermeer, [1989](https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.13132#nph13132-bib-0100)). Intercropping is common, particularly in countries with high amounts of subsistence agriculture and low amounts of agricultural mechanisation. Intercropping is often undertaken by farmers practicing low-input (high labour), low-yield farming on small parcels of land (Ngwira *et al*., [2012](https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.13132#nph13132-bib-0064)). Under these conditions, intercropping can support increased aggregate yields per unit input, insure against crop failure and market fluctuations, meet food preference and/or cultural demands, protect and improve soil quality, and increase income (Rusinamhodzi *et al*., [2012](https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.13132#nph13132-bib-0078)). The inclusion of legumes as intercrops in cereals and oilseeds under pulse based intercropping sequences would have a positive effect on the productivity, economics and fertility status of the soil (Reddy *et al* 2015). Legume intercropping system plays a significant role in the efficient utilization of resources. Cereal-legume intercropping is a more productive and profitable cropping system in comparison with solitary cropping (Evans *et al*., 2001). India is second largest cotton producing country in the world which stands first in area (12.92 M ha) and second in production (37 M bales) with productivity of 443 kg ha-1 (Directorate of Economics and Statistics, DA & FW, Ministry of Agriculture & Farmers Welfare, New Delhi (2023). In India, Soybean is grown in an area of 10.84 million hectares with an annual production of about 14.68 million tons and productivity of 1354 kg ha-1. India accounts for 90 per cent of world’s pigeon pea growing area and 85 per cent of world’s production. It is grown an area of 3.88 M ha with the production of 3.17 million tons and productivity of 849 kg ha-1 (Pradhan *et al*., [2019).](https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.13132#nph13132-bib-0064) Keeping major rain fed crops in view, an attempt was made to evaluate pulses based intercropping systems in Cotton and Soybean which are major cash crops of rain fed regions to bring stability, productivity and profitability against climate risks in selected villages of Akola district of Maharashtra.

2. material and methods

The steps followed in selection of sites in districts include analysis of climate constraints of village based on long term data assessment of natural resources, identification of major faming situations, constraints of crop production, climate vulnerabilities, yield gaps and opportunities for climate change adaptations based on the detailed analysis, action plan to demonstrate appropriate intercropping systems to meet climate vulnerability (drought) was prepared on participatory mode with the help of scientists and farmers. The demonstrations were implemented during the *Kharif* 2021-22, 2022-23 and 2023-24.

The farmers in the selected villages of the Warkhed and Kajleshwar were stratified based on size of holding into marginal (>1ha), small (1-2 ha), medium (2-4 ha) and large farmers (>4 ha). The farmers were also stratified based on soil type such as shallow, medium and deep in Soybean+Pigeonpea intercropping demonstrations whereas medium and deep in Cotton+Greengram intercropping. The training programs on production skills of different intercropping system were imparted to the participants before conducting the demonstrations. The demonstrations on the improved intercropping systems along with the sole crops were conducted in 0.40 ha area on each farmer’s site in selected adopted villages (Table 1).

After the harvesting of intercrops, the yield of intercrops were recorded and residues of intercrops i.e. greengram and soybean are mulched in cotton and pigeonpea crops. The grain equivalent yield was worked out and economic analysis of inputs and output relationship was analyzed to quantify the benefits of interventions for last three years. Equivalent yield for each intercropping system was calculated based on the yield of individual crops in each intervention and their market prices prevailing at the time of experimentation for comparison of intercropping system with sole crop.

Soybean yield equivalent for soybean+pigeonpea intercropping was calculated as described by following formula (Prasad and Srivastava 1991):

Soybean equivalent yield (q ha-1) with Pigeonpea = ((Soybean grain yield (q ha-1) x rate of Soybean) + (Pigeonpea grain yield (q ha-1) x rate of Pigeonpea))/ rate of Soybean.

Note -Rate of Soybean =4600 Rs/q, Pigeon pea =7000 Rs/q. MSP rates were taken for study.

Similarly, the equivalent yield for Cotton+Greengram intercropping was calculated by the formula:

Cotton equivalent yield (q ha-1) with Greengram = ((Seed Cotton yield (q ha-1) x rate of Cotton) + (Greengram grain yield (q ha-1) x rate of Greengram))/ rate of Cotton.

Note -Rate of Cotton =7020 Rs/q, Greengram =8558 Rs/q,

**Table 1. Area, number of farmers and rainfall under Soybean+Pigeonpea intercropping systems.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Village** | **Cropping system** | **Crop Varieties** | **Year** | **Area**  **(ha)** | **Number of farmers** | **Rainfall (mm)** | | | |
| **N** | **A** | **Kharif**  **(June-Sept)** | **Rabi**  **(Oct-Dec)** |
| Village Warkhed Taluka-Barshitakli, District- Akola | Soybean+  Pigeonpea (4:2)  Soybean+  Pigeonpea (6:1)  Sole Soybean | Soybean-JS-335  Pigeonpea- PKV Tara | 2021-22 | 3.60 | 09 | 807.0 | 1043 | 904 | 139 |
| 2022-23 | 3.60 | 09 | 807.0 | 999 | 960 | 39 |
| 2023-24 | 3.60 | 09 | 807.0 | 574 | 554 | 20 |
| Village Kajleshwar Taluka-Barshitakli, District- Akola | Soybean+  Pigeonpea (4:2)  Soybean+  Pigeonpea (6:1)  Sole Soybean  Soybean-JS-335  Pigeonpea- PKV Tara | Soybean-JS-335  Pigeonpea- PKV Tara | 2021-22 | 3.60 | 09 | 807.0 | 1043 | 904 | 139 |
| 2022-23 | 3.60 | 09 | 807.0 | 999 | 960 | 39 |
| 2023-24 | 3.60 | 09 | 807.0 | 574 | 554 | 20 |
|  |  |  | **Total** | **21.60** | **54** |  |  |  |  |

**Table 2. Area, number of farmers and rainfall under Cotton+Greengram intercropping systems.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Village** | **Cropping system** | **Crop Varieties** | **Year** | **Area**  **(ha)** | **Number of farmers** | **Rainfall (mm)** | | | |
| **Normal** | **Actual** | **Kharif (Jun-Sept)** | **Rabi**  **(Oct-Dec)** |
| Village Warkhed Taluka-Barshitakli, District- Akola | Cotton+ Greengram (1:1) and  Sole Cotton | *Bt.* Cotton–Mallika  Greengram - Utkarsha | 2021-22 | 2.40 | 06 | 807.0 | 1043 | 904 | 139 |
| 2022-23 | 2.40 | 06 | 807.0 | 999 | 960 | 39 |
| 2023-24 | 2.40 | 06 | 807.0 | 574 | 554 | 20 |
| Village Kajleshwar, Taluka-Barshitakli, District- Akola | Cotton+ Greengram (1:1) and  Sole Cotton | *Bt.* Cotton–Mallika  Greengram - Utkarsha | 2021-22 | 2.40 | 06 | 807.0 | 1043 | 904 | 139 |
| 2022-23 | 2.40 | 06 | 807.0 | 999 | 960 | 39 |
| 2023-24 | 2.40 | 06 | 807.0 | 574 | 554 | 20 |
|  |  |  | **Total** | **14.40** | **24** |  |  |  |  |

**2.1.Rainfall pattern at experimental sites**

The villages Warkhed (Bk) and Kajleshwar are in Barshitakli taluka of Akola district of Maharashtra State is situated between 77O7' 00’’ to 77O 10' 00’’ E longitude and 20O 32’ 30’’ to 20O 35' 00'' N latitude and covers area of 198 ha and 754 ha respectively. The mean elevation of the area is about 325 m above mean sea level. Villages Warkhed and Kajleshwar are situated at about 26 and 32 km south and east of Akola city respectively. The villages receive normal rainfall of 807.0 mm. The villages normally received an average rainfall of 806 mm rainfall during the *Kharif* season and 66mm rainfall during the *Rabi* season as estimated from the rainfall received during the last three years i.e. 2021-22, 2022-23 and 2023-24. The total rainfall received in the villages was 1043, 999, and 574 mm which was higher than normal rainfall by 29.2% and 23.8% for the years 2021-22 and 2022-23 whereas total rainfall is deficit by -28.8% in the year 2023-24 which reflects the climate vagaries in the region which is coupled with both heavy rainfall events and prolonged dry spells. The seasonal distribution of rainfall during these years depicts that during the Kharif season received rainfall higher than normal by 12.0% and 18.9% during 2021-22 and 2022-23 whereas it was deficit by -31.3% in year 2023-24. In the case of the *Rabi* season, there was higher rainfall during the year 2021-22 by 39% whereas it was deficit by -61% and -80% during 2022-23 and 2023-24. During the year 2021-22 and 2022-23 the onset of monsoon is normal i.e around 7-11 June whereas in 2023-24 the sowing has been delayed up to second week of July and sowing is delayed for around one month due to late onset of monsoon during this year. These different situations of seasonal rainfalls and unpredictable behaviour of rainfall which was coupled with late-onset, prolonged dry spells and heavy rainfall events makes region climate vulnerable.

3. results and discussion

Assessment of intercropping systems of soybean + pigeonpea (4:2)/ soybean + pigeonpea (6:1) with 54 farmers in 21.0 ha area and cotton + greengram (1:1) with 24 farmer demonstrations implemented on an area of 14.40 ha in black soils of Warkhed and Kajlehswar villages, Taluka – Barshitakali, District-Akola in Maharashtra state were conducted during the year 2021-22 to 2023-24 in action research participatory mode through NICRA project implemented by AICRP for Dryland Agriculture, Dr. PDKV, Akola.

During the year of 2021-22 to 2023-24, the results showed that intercropping of soybean + pigeonpea (4:2) recorded higher soybean equivalent yield 2066, 2088 and 2136 kg ha-1 compared to the soybean + pigeonpea (6:1) 1895, 1897, and 1894 kg ha-1 and sole crop which recorded 1498, 1623, and 1186 kg ha-1 yield respectively in village Warkhed.

Similar trend of results were obtained in village Kajleshwar wherein intercropping of soybean + pigeonpea (4:2) recorded higher soybean equivalent yield 2052, 1932 and 1963 kg ha-1 compared to the soybean + pigeonpea (6:1) 1886, 1721, and 1680 kg ha-1 and sole crop which recorded 1512, 1548, and 1123 kg ha-1 yield respectively (Table 3).

From the given data sets it was observed that, on average the intercropping system of soybean + pigeonpea (4:2) has given significantly higher soybean equivalent yield (2040 kg ha-1 ), net monetary returns (Rs.80891/- ha-1) and B:C ratio (3.65). Soybean + pigeonpea (6:1) also significantly enhanced the soybean equivalent yield which was 1829 kg ha-1 and B:C ratio of 3.03 which was higher than sole soybean i.e 1415 kg ha-1 with B:C ratio of 2.59. These results are in agreement with the findings of Prasad and Srivastava (1991). Rainwater use efficiency was also found to be higher in the soybean + pigeonpea (4:2) intercropping system (2.79) followed by the soybean + pigeonpea (6:1) intercropping system (2.24) which was higher than sole soybean (1.70). Lakhena and Maurya (2009) and Turkhede *et al.* (2015) reported that the intercropping system reduced the yield of the main crop and significantly increased the grain equivalent yield over the sole crop. Reddy *et al.* (2015) reported that the, soybean + pigeonpea system gave benefit to the extent of 40-60% in different sites of Kurnool in Andhra Pradesh, Aurangabad and Nandurbar districts of Maharashtra.

**Table 3: Productivity and profitability of intercropping system of soybean +pigeonpea in medium black soils of village Warkhed and Kajleshwar in Akola District**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Name of Village** | **Year** | **Cropping System** | **Grain Yield**  **(Kg ha-1)** | | **Grain Equivalent Yield**  **(Kg ha-1 )** | **NMR (Rs.ha-1 )** | **B:C Ratio** | **RWUE**  **(Kg ha-1mm-1)** |
| **Soybean** | **Pigeonpea** |
| Warkhed | 2021-22 | Sole Soybean | 1498 | - | 1498 | 49546 | 2.79 | 1.43 |
| Soybean+Pigeonpea (4:2) | 1206 | 699 | 2066 | 85468 | 3.79 | 2.15 |
| Soybean+Pigeonpea (6:1) | 1250 | 524 | 1895 | 67717 | 3.20 | 1.81 |
|  |  |  |  |  |  |  |  |
| 2022-23 | Sole Soybean | 1623 | - | 1623 | 55804 | 3.00 | 1.69 |
| Soybean+Pigeonpea (4:2) | 1290 | 649 | 2088 | 87071 | 3.84 | 2.29 |
| Soybean+Pigeonpea (6:1) | 1375 | 424 | 1897 | 68027 | 3.21 | 1.90 |
|  |  |  |  |  |  |  |  |
| 2023-24 | Sole Soybean | 1186 | - | 1186 | 29158 | 2.07 | 2.07 |
| Soybean+Pigeonpea (4:2) | 1256 | 616 | 2136 | 82133 | 3.69 | 4.10 |
| Soybean+Pigeonpea (6:1) | 1325 | 374 | 1894 | 61013 | 3.00 | 3.30 |
|  |  |  |  |  |  |  |  |  |
| Kajleshwar | 2021-22 | Sole Soybean | 1512 | - | 1512 | 50193 | 2.81 | 1.44 |
| Soybean+Pigeonpea (4:2) | 1134 | 746 | 2052 | 84648 | 3.77 | 2.33 |
| Soybean+Pigeonpea (6:1) | 1262 | 507 | 1886 | 66844 | 3.18 | 1.80 |
|  |  |  |  |  |  |  |  |
| 2022-23 | Sole Soybean | 1548 | - | 1548 | 52049 | 2.87 | 1.61 |
| Soybean+Pigeonpea (4:2) | 1176 | 615 | 1932 | 75610 | 3.49 | 2.26 |
| Soybean+Pigeonpea (6:1) | 1326 | 321 | 1721 | 58585 | 2.92 | 1.72 |
|  |  |  |  |  |  |  |  |
| 2023-24 | Sole Soybean | 1123 | - | 1123 | 26280 | 1.97 | 1.96 |
| Soybean+Pigeonpea (4:2) | 1136 | 581 | 1963 | 70414 | 3.34 | 3.60 |
| Soybean+Pigeonpea (6:1) | 1273 | 268 | 1680 | 50190 | 2.65 | 2.92 |
|  |  |  |  |  |  |  |  |  |
| **Overall Mean** | **Mean** | **Sole Soybean** | **1415** | **-** | **1415** | **43838** | **2.59** | **1.70** |
| **Soybean+Pigeonpea (4:2)** | **1200** | **651** | **2040** | **80891** | **3.65** | **2.79** |
| **Soybean+Pigeonpea (6:1)** | **1302** | **403** | **1829** | **62063** | **3.03** | **2.24** |

In cotton + greengram intercropping system, cotton equivalent yield and B:C ratio were found higher i.e 1852, 2587, 2147 kg ha-1 with higher B:C ratio (2.46, 3.19, 2.99) over the sole cotton with yield of 1524, 2039 and 1739 kg ha-1 and B:C ratio of (2.42, 3.06, 2.70) over period of three years 2021-22, 2022-23 and 2023-24 respectively in Warkhed Village.

Similar trends of results were also obtained in village Kajleshwar wherein the cotton + greengram intercropping system showed higher cotton equivalent yield i.e 1961, 2327 and 1820 kg ha-1 with higher B:C ratio (2.46, 3.19, 2.99) over the sole cotton with yield of 1317, 1731 and 1518 kg ha-1 and B:C ratio of (2.09, 2.70, 2.43) over period of three years respectively.

On an average, cotton + greengram (1:1) recorded higher cotton equivalent yield (2116 Kg ha-1), net monetary returns (Rs.95399/- ha-1), B:C ratio (2.82) and rainwater use efficiency (2.58) over sole cotton which has recorded yield of 1645 Kg ha-1, net monetary returns (Rs.74035/- ha-1), B:C ratio (2.57) and rainwater use efficiency (2.03). Any short - duration intercrop used in the system will pay the farmer and much-needed interim income or meet the domestic requirement of food and fodder also reported by Rao (1991) and Patel *et al*. (2013).

**Table 4: Productivity and profitability of intercropping system of cotton + greengram (1:1) in medium black soils of village Warkhed and Kajleshwar in Akola District**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Name of Village** | **Year** | **Cropping System** | **Yield**  **(Kg ha-1)** | | **Cotton Equivalent Yield**  **(Kg ha-1)** | **NMR (Rs.ha1)** | **B:C Ratio** | **RWUE** |
| **Cotton** | **Greengram** |
| Warkhed | 2021-22 | Sole Cotton | 1524 | - | 1524 | 64477 | 2.42 | 1.46 |
| Cotton + Greengram (1:1) | 1226 | 664 | 1852 | 74738 | 2.46 | 1.77 |
| 2022-23 | Sole Cotton | 2039 | - | 2039 | 98987 | 3.06 | 2.04 |
| Cotton + Greengram (1:1) | 1726 | 914 | 2587 | 120726 | 3.19 | 2.59 |
| 2023-24 | Sole Cotton | 1739 | 0 | 1739 | 79205 | 2.70 | 3.03 |
| Cotton + Greengram (1:1) | 1414 | 602 | 2147 | 102879 | 2.99 | 3.74 |
|  |  |  |  |  |  |  |  |  |
| Kajleshwar | 2021-22 | Sole Cotton | 1317 | - | 1317 | 57473 | 2.09 | 1.26 |
| Cotton + Greengram (1:1) | 1280 | 723 | 1961 | 84875 | 2.64 | 1.88 |
| 2022-23 | Sole Cotton | 1731 | - | 1731 | 79051 | 2.70 | 1.73 |
| Cotton + Greengram (1:1) | 1505 | 873 | 2327 | 108185 | 3.01 | 2.33 |
| 2023-24 | Sole Cotton | 1518 | - | 1518 | 65015 | 2.43 | 2.65 |
| Cotton + Greengram (1:1) | 1167 | 536 | 1820 | 80990 | 2.62 | 3.17 |
|  |  |  |  |  |  |  |  |  |
| **Overall Mean** | **Mean** | **Sole Cotton** | **1645** | **-** | **1645** | **74035** | **2.57** | **2.03** |
| **Cotton+Greengram (1:1)** | **1386** | **719** | **2116** | **95399** | **2.82** | **2.58** |

4. Conclusion

The assessment studies on the intercropping system in the black soil of Akola districts of Maharashtra, indicated that soybean + pigeonpea (4:2) / soybean + pigeonpea (6:1) and cotton + greengram (1:1) were found more sustainable intercropping systems than sole cropping which proved resilient to climate vagaries. Thus, intercropping offers a solution to obtain higher yield per unit area and reduced risk of crop failure under unpredictable rain fed conditions of the Vidarbha region.

## **DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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