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Impact of mitigation technologies

on rainy season pulse crops from climatic abnormalities

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The major reasons of fluctuating per caput availability and price of pulses are climatic abnormalities in India. The climatic abnormalities are more vulnerable on pulse crops compared with oilseeds and cereals. The abiotic climatic vulnerabilities are affecting rainy season pulse crops by temporary water submergence; mid-and late-season drought; photo-thermo sensitivity and heat stress during grain filling stage. Besides under biotic stress increases wilt, leaf blight, Cercospora *leaf spot, yellow vein mosaic, pod borer indirectly. Adoption of improved technologies, resistant/ tolerant cultivars is essential to neutralize the effect of abiotic and biotic stresses enhanced productivity and economic benefits from green gram, black gram, pigeon pea and cluster bean compared with farmers' practices. Under these conditions, adoption of improved mitigation technologies/cultivars increases grain yield of green gram, black gram, pigeon pea and cluster bean ranged from 0.73 to 0.96, 0.78 to 0.93, 1.62 to 2.32 and 1.58 to 1.82 tonne/ha when compared with average from 2012 to 2016 yield of 0.40, 0.51, 0.74 and 0.51 tonne/ha of Country, respectively. Similarly, using improved techniques for mitigation of climatic abnormalities gave higher net returns and benefit cost ratio when compared with practices followed by farmers.*

Key words: Climatic abnormalities, Mitigation, Pulses, Rainy season

Pulses are contributing significantly to the nutritional security of the majority population of the country. The availability of 17.1 to 25.8% protein in pulse grains makes it an important rich source of supplementing the energy. The yield of pulses has remained virtually stagnant for the last four decades. The average productivity at global level is about 0.80 tonne/ha, while of India is > 0.75 tonne/ha. Similarly, area of pulse crops has not increased much during the past 60 to 65 years. Due to stagnant production and ever increasing population, the net per caput availability of pulses has come down from 60.7 g/person/day in 1951 to 43.3 g/person/day during 2013.

India is the largest producer, consumer and importer of pulse in the World. Pulses are grown in an area range of 23.28 to 26.40 million ha with an annual production fluctuating between 14.55 and 19.57 million tonne in last five years. In general, this low and fluctuations in total production and productivity of pulses are ascribed to crop affected by various forms of abiotic and biotic stresses in different regions of the country. Ironically, India's pulse production touched 19.57 million tonne from 24.5 million ha area in 2013-14, but it declined (17.15 mt) during 2014-15, as consequences to unfavourable direct and indirect effect of weather abnormalities during crop season. Due to stagnant production and fulfilling of demand of ever increasing population, the import of pulses crossed about 5 mt during 2015-16.

To fulfil growing demand and save precious foreign currency, pulses production need to increase from present level of 17.33 mt (2015-16) to 26.5 mt by 2020A.D.

In India, six states (Madhya Pradesh is the largest producer of pulses followed by Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh and Karnataka) are together contributing 79% area and 80% production, whereas four states (Jharkhand, Odisha, Bihar and Chhattisgarh) have ample scope exists to increase coverage and enhance productivity of pulses. Due to the uncertain low productivity, low income and low input nature, pulses are grown as residual/alternate crops on marginal lands in rainfed areas after taking care of food/income needs from high productivity high input crops like paddy and wheat by most farmers. Also, they are grown as rainfed crops with limited application of inputs. However, limited information is available on climatic stresses effect on performance of mitigation technologies to abiotic and biotic stresses on major pulse crops *viz.* green gram, black gram, pigeon pea and cluster bean crops.

Multiple climatic stresses

Adverse effects of climate change are more pronounced in pulse crops compared to oilseed and cereal crops. Pulse crops are more vulnerable even to the fluctuations of weather conditions. Climate change is affecting our agriculture owing to 0.74°C average global increase in temperature in the last 100 years and atmospheric CO_2 concentration increase from 280 ppm in 1750 to 400 ppm in 2013. The increase of temperature of 3° to 4°C could reduce crop yields by 15 to 35%. The frequency of occurrences of extreme weather events such as changes in rainfall patterns, particularly late onset of monsoon, uneven distribution of rain, short-term waterlogging, mid-or late-season drought, floods, heat stress during flowering, fertilization and grain filling stage and cyclones has rise' in recent years than in the past during *kharif* (rainy). The pulse crop requires cold temperatures during vegetative growth and warm temperatures at maturity; the optimum temperature for growth is 18° to 30°C. Similarly, nitrogen-fixation through symbiotic association of *Rhizobium* sp. is also virtually declined at temperature exceeding beyond 35 °C. Depending on the intensity, duration, and stage of exposure, heat stress can adversely affect delayed flowering, flower abortion, reduced number and size of flower, deformity of floral organs during flowering stage, impaired fertilization and post-fertilization, small endosperm, reduced pre-embryo and fertilized embryo, embryo abortion, poor fruit set at fertilization period, and like-wise during grain filling stage altered source sink relations, aborted seed. Moreover, drought and high temperature interact together, and the damaging effect of both the stresses together is far more severe than individual effect. Based on physiological studies, major *kharif* pulse crops are categorized as per thermo tolerance in the order of cluster bean > green gram > pigeon pea > black gram.

Abiotic climatic stress

The major abiotic climatic vulnerabilities are occasionally late onset of monsoon, mid-or late-season drought and water-logging, uneven distribution and untimely rains, frost, etc. The major abiotic stresses are water submergence during early stage of crop, photo-thermo sensitivity, late season drought, heat stress at flowering and pod formation stage affecting all major *kharif* pulses, excess growth due to high moisture content in soil and drought during reproductive stage of cluster bean, respectively. The water-logging during establishment stage, mid-and late-season drought in short and long duration pigeonpea cultivars, moreover long duration cultivars affected by frost, chilling temperature and heat waves. Drought stress alone may reduce seed yields by 50% in the arid and semi-arid regions. In Central India, moisture stress due to low water holding capacity of the soil often limits grain yield on Alluvial soil, whereas in Black Soil, high water holding capacity causes reduction in growth and yield. Grain yield is mainly influenced by temperature.

Biotic climatic stress

Climate change abnormalities have increased the intensity of biotic stresses indirectly. Wilt and root rot increases in dry condition and excess moisture, whereas *Cercospora* rust disease increases due to excess soil moisture and humidity. The climate change abnormalities are one of the factors which regulate the density of insect pests in blackgram ecosystem. In India, quantitative avoidable losses (7 to 35%) caused by insect pest complex in black gram vary with different agro-climatic conditions, whereas combined infestation of pests and diseases in black gram annual estimated yield lose over 30% in dry land conditions. Similarly, yield losses in black gram by 67% due to yellow mosaic virus in irrigated conditions. Among insect pest, pod borer (*Helicovera armigera*) complex causes the greatest harm, followed by yellow vein mosaic virus, pod fly, wilt and root rot. Pod borer and sterility mosaic virus damage increases due to rise of temperature and prevalence of cloudy weather conditions. Poor drainage/water stagnation during the rainy season causes heavy losses to pigeon pea on account of low plant stand and increased incidence of *Phytophthora* blight disease. Yellow mosaic virus in green gram and black gram is due to white fly and fly increases under high humidity and slight increased temperature. Also, *Phytopthora* leaf blight, bacterial blight and *Cercospora* during vegetative growth stage in cluster bean are common and more damaging under high rainfall conditions. All insect pests of study showed negative correlation with maximum temperature while positive correlation with maximum relative humidity and total rainfall.

Impact of technological demonstrations

For technological interventions, component demonstrations were conducted under NICRA project under KVK. The climate of this zone is characterized as semi-arid, extremely cold during December-January (-1.0°C min. temperature) where as hot during May-June (49°C max. temperature). Average annual rainfall of this zone is 701 mm, mostly concentrated in July and August. The minimum and maximum temperature ranges were 0° to 47.5°C, 4° to 47°C and 3° to 48°C, whereas total rainfall received 1074, 1028 and 482 mm, during 2012-13, 2013-14 and 2014-15, respectively. The maximum concentration of rains is in July and August in comparision to other months. Out of experimentation years, minimum temperature 0°C was recorded on 8 January 2013 and frost infestation was also seen.

The soil was neutral in nature and loam, sandy loam and clay loam in texture. In general, the soil was low in organic matter, available N, P, S and Zn. The water-table was 25 to 31 m below the surface. Permeability and drainage conditions of these soils range from moderate to high. The demonstrations on selected crops were carried out during *kharif*

Table 1. Impact of different technological interventions for different climatic stresses of green gram (3 year mean)

Climatic problem	Intervention	Grain yield (tonne/ha)	Cost of production (₹/ha)	Net returns(₹/ha) abiotic stress	B:C ratio
Temporary water-logging	FP-Sowing on flat land	0.61 (1.42)	14,100	16,227	2.15
	IT-Broad bed furrow sowing	0.73 (1.73)	13,620	22,418	2.65
Drought due to early	FP-Rainfed	0.35 (0.79)	13,880	03542	1.26
withdrawal of monsoon	IT- Irrigation before wilting conditions	0.90 (1.65)	15,435	29,602	2.92
Biotic stress					
Yellow vein mosaic due	FP-Old cultivar JN-721	0.78 (1.76)	14,400	24,216	2.68
to high humidity	IT-Cultivar SML-668	0.96 (2.16)	15,150	32,362	3.14

FP-Farmers' practice; IP-Improved technology; figure in parenthesis indicates straw yield

between 2012 and 2015 to evaluate the escaping effect of climatic vulnerability by using techniques such as method of sowing, using pulse cultivars tolerant to pod borer, wilt, heat and drought etc. Each demonstration was selected for assessment of technology against climatic vulnerability as compared to practices followed by farmers. The crops of pulses such as blackgram, green gram, pigeonpea and cluster bean was sown in time and recommended agronomical package of practices of Vishwa Vidyalaya were followed. Grain, straw yield, net return and cost benefit ratio were calculated to find out the economics of demonstrations. Different economic indicators of inputs were calculated based on the minimum support price and existing market price.

Green gram

Results of demonstrations showed that temporary waterlogging in *kharif* season significantly influenced the average grain and straw yield of green gram (Table 1). The average grain and straw yield of green gram was between 20 and 22% higher under sowing of crop with broad bed furrow (BBF) sowing (Figs. 1 and 2) compared to control. Like-wise drought due to early withdrawal of monsoon crop severally affected during flowering and grain filling stage. Irrigation at wilting point conditions increased grain and straw yield by 157 and 109%, respectively, compared with farmers' practice. The irrigation during drought conditions gave maximum additional net return ₹ 26,060/ha, while sowing of crop with BBF method gave additional ₹ 6,191/ha compared with practices followed by farmers'. Similarly, benefit cost (B:C) ratio was higher under improved technologies compared with farmers' practices.

The crop suffered from yellow vein mosaic virus (YMV) disease during *kharif* season due to high humidity in rainy season. Adoption of YMV resistant cultivar SML-668 resulted in increase of grain and straw yields by 23 and 17%, respectively compared to old cultivar JN-721 (Table 1). The improved technologies YMV resistant cultivar gave maximum additional net return ₹ 8,146/ha when compared with practice followed by farmers'. Similarly, B:C ratio was 3.14 under YMV resistant cultivar, while 2.68 with old cultivar.

Black gram

During rainy season, the crop is often affected by waterlogging due to intensive rains. Results of trials (Fig. 3) showed that the sowing of black gram crop with BBF influenced the average grain and straw yields compared with traditional method of sowing (Table 2). The average grain and straw yield of blackgram was between 24 and 20% higher under sowing of crop with BBF compared with traditional method of sowing. Photo-thermo sensitive cultivar PU-35 produced significantly higher grain and straw yield as compared to traditional existing old cultivar T-9. The average grain and straw yields were 23% and 20% respectively, higher compared with old cultivar. The improved technologies/resistant cultivars increased net return and B:C ratio than farmers' practice.

The yellow vein mosaic virus disease during *kharif* due to high humidity in rainy season also infected the crop. The YMV resistant cultivar

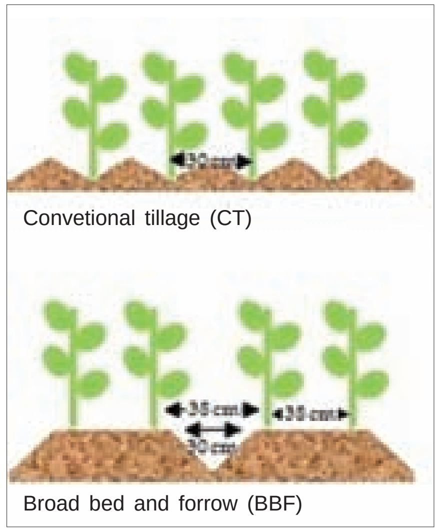

Fig. 1. Sowing methods


Fig. 2. Green gram crop stand on BBF

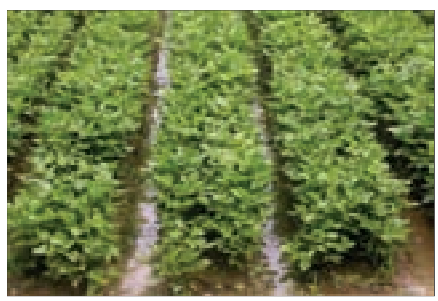
Fig. 3. Black gram crop on bed under water logging condition

Shekhar-2 increased grain and straw yields by 18 and 16%, respectively when compared with existing old cultivar T-9. Growing of YMV resistant cultivar Shekhar-2 gave

Table 2. Impact of different technological interventions for different climatic stresses to black gram (3 year mean)

Climatic problem	Intervention	Grain yield (tonne/ha)	Cost of production (₹/ha)	Net returns (₹/ha)	B:C ratio
Abiotic stress					
Temporary water logging	FP-Sowing on flat land	0.75 (1.77)	16,810	19,015	2.13
	IT-Broad bed furrow sowing	0.93 (2.20)	16,150	28,431	2.78
Photothermo-sensitivity	FP- Old cultivar T-9	0.74 (1.75)	14,560	20,980	2.44
	IT- Resistant cultivar PU-35	0.91 (2.10)	15,534	27,556	2.76
Biotic stress					
Yellow vein	FP- Old cultivar T-9	0.66 (1.56)	16,100	15,603	1.97
mosaic due to high humidity	IT- Resistant cultivar Shekhar-2	0.78 (1.84)	16,930	20,429	2.21

FP, Farmers' practice; IT, Improved technology, Figure in parenthesis indicates straw yield

additional net returns of ₹ 4,826/ha when compared with existing old cultivar. Similarly, higher B:C ratio under improved resistant cultivar compared with old cultivars (farmers' practice).

Pigeonpea

The survivability of pigeonpea crop at early stages is often affected by temporary water submergence that may vary from hours to a few days. The sowing of crop with BBF (Fig. 4) saved of crop from water submergence and increased the grain and stalk yield of pigeon pea over conventional sowing method (Table 3). The increase in grain and stalk yields was 18% and 17% under BBF sowing compared with line sowing on flat land. Similarly, long duration cultivars of pigeonpea often suffer from frost in north-western and central India. The short duration cultivars of pigeonpea are harvested before possible time of frost in January. Short duration maturity cycle cultivar Pusa-992 produced higher grain and stalk yield when compared with long duration maturity cycle cultivar JA-3. The average grain and stalk yields were 34 and 31% higher in short duration cultivar compared with long duration

Fig. 4. Broad bed furrow sowing

cultivars during frost affected years. Demonstrations on drought management through extra early maturing cultivar (ICPL-88039) also influenced the average grain and stalk yield of pigeonpea. The average grain and stalk yield of pigeonpea was 23% and 14% higher under extra early maturing cultivar compared to long duration cultivar (Gwalior-3) during drought years. The maximum additional return (₹ 31,364/ha) was obtained from escaping of crop from frost followed by drought and minimum with temporary water-logging, respectively. Similar trend was obtained of B:C ratio under abiotic stresses.

The *Cercospora* leaf blight is managed through use of resistant cultivar Pusa 2002. The average grain and stalk yields of pigeonpea were increased by 20.7% and 23.4% with recommended cultivar Pusa 2002 for control of *Cercospora* leaf spot as compared to local cultivar (Table 3). The recommended technology for control of pod borer (use of pheromon trap @ 20 + HaNPV 500 LE + *quinolphos* 25 EC @ 750 ml/ha at ETL level) produced significantly higher grain and stalk yields of pigeonpea compared to use of *quinolphos* 25 EC @ 750 ml/ha (FP). The average grain and stalk yields of pigeonpea were 42 and 6% respectively, higher with recommended technique for control of pod borer compared to farmers' practice. Results of wilt management recommended technique (seed treatment with *Trichoderma* @ 10 g/ kg seed and sowing of pigeonpea on broad bed furrow) increased the average grain and stalk yield of pigeonpea compared to farmers' practice. The average grain and stalk yield of pigeonpea was 26% and 40% higher with recommended technique as compared to control. The maximum additional return ₹ 24,170/ha was obtained with control of wilt, while ₹ 24,060/ha with pod borer management compared with farmers' practice. Similar B:C ratio also improved with improved technology.

Cluster bean

The cluster bean is usually affected by temporary water submergence during early stage of crop. The broad bed furrow (BBF) sowing saved the crop from rainwater submergence and increased the grain and straw yield of cluster bean over conventional sowing method (Table 4). The increase in grain and straw yields was 13 and 8% under BBF sowing method compared with conventional sowing (FP). Long duration cultivars of cluster bean occasionally suffer from drought in north-western and central India. The drought tolerant cultivar RGC-1003 of cluster bean produced higher grain and straw yields as compared to long duration cultivar HG 365. The average grain and straw yields were 16% and 13% higher than long duration cultivar. The maximum additional net returns of ₹ 7,172/ha was obtained with saving of crop from drought through using tolerant cultivar followed by ₹ 4,739/ha with BBF sowing compared with farmers, practice. Similar trend of benefit cost ratio was obtained.

Under excess moisture conditions, leaf blight disease infestation increases in cluster bean resulting in decrease of yield. Under these conditions, spray of carbon oxychloride @ 0.3% at 10 to 12 days

Table 3. Impact of different technological interventions for different climatic stresses to pigeonpea (3 year mean)

Climatic problem	Intervention	Grain yield (tonne/ha)	Cost of production (₹/ha)	Net returns (₹/ha)	B:C ratio
Abiotic stress temporary water-logging	FP- Line sowing on flat land IT- Broad bed furrow sowing	1.37 (6.44) 1.62 (7.52)	20,200 20,450	48,905 61,063	3.42 3.99
Frost attack in long duration variety	FP- Long duration cultivar JA-3 IT- Short duration cultivar Pusa-992	1.73 (8.05) 2.32 (10.56)	22,110 20,050	65,197 96,561	3.95 5.82
Drought in pigeon pea	FP- Long duration cultivar Gwalior-3	1.85 (8.23)	22,884	69,753	4.05
	IT- Extra early maturing cultivar ICPL-88039 escaping drought	2.28 (9.98)	24,110	89,605	4.72
Biotic stress					
Cercospora leaf blight infestation	FP- Old cultivar UPAS-120 IT- Resistant cultivar Pusa-2002	1.79 (8.23) 2.16 (10.15)	21,810 22,570	68,281 86,636	4.13 4.84
Pod borer complex	FP- Quinolphos 25 EC @750 ml/ha	1.52 (9.42)	19,800	61,274	4.10
	IT- Pheromon trap @ 20 + HaNPV 500 LE + *Quinolphos* 25 EC @ 750 ml/ha	2.15 (9.97)	23,100	85,334	4.69
Wilt	FP- Not adopted any practice IT- Cultivar Pusa-992 + Seed treatment with *Trichoderma* @ 10 g/kg seed and broad bed and furrow sowing	1.78 (7.47) 2.25 (10.44)	23,450 24,450	64,870 89,040	3.77 4.64

FP-Farmers' practice; IP-Improved technology; Figure in parenthesis indicates stalk yield

Table 4. Impact of different technological interventions for different climatic stresses to cluster bean (3 year mean)

Climatic problem	Intervention	Grain yield (tonne/ha)	Cost of production (₹/ha)	Net returns (₹/ha)	B:C ratio
Abiotic stress					
Excess growth due to high soil moisture	FP- Line sowing on flat land IT- Broad bed furrow sowing	1.40 (2.68) 1.58 (2.89)	17,099 19,214	35,687 40,426	3.09 3.10
Terminal drought infestation	FP- Old cultivar HG-365 IT- Tolerant cultivar RGC-1003	1.42 (2.44) 1.64 (2.76)	18,530 19,408	34,504 41,676	2.86 3.15
Biotic stress					
Leaf blight due to excess soil moisture	FP- Not adopted any practice	1.53 (2.69)	18,870	47,616	3.04
	IP- Carbon oxychloride @ 0.3% at 10 to 12 days interval	1.79 (3.16)	19,420	58,527	3.45
Cercospora disease due to excess soil moisture	FP- Not adopted any practice IP- Spray of Mancozeb @ 2 g/lit. of water	1.58 (2.77) 1.82 (3.13)	19,615 20,890	39,721 47,061	3.02 3.03

FP-Farmers' practice; IP-Improved technology; figure in parenthesis indicates straw yield

interval increased the grain and straw yields by 17 and 18% compared with farmers' practice (Table 4). Similarly, under excess moisture conditions, *Cercospora* disease attacked cluster bean crop. The recommended technology for control of *Cercospora* disease (spray of mancozeb @ 2 g/lit water) produced higher grain and straw yield of cluster bean compared to farmers practice (not adopted any practice). The average grain and straw yield of cluster bean was 15 and 13% higher with recommended technique for control of *Cercospora* disease compared to farmers' practice. The maximum additional net returns of ₹ 10,911/ha was obtained with control of leaf blight followed by ₹ 7,340/ha when compared with farmers practice. Similar trend of benefit : cost ratio (B:C) was obtained.

Adaptation strategies

The impact of climate changes are complex and no single strategy will address these issues adequately. A combination of technology and policy related interventions are required. Considering the natural resources, cropping systems, production technologies are required as per projected climate scenario.

Future Prospects

The following strategies for futures are essential for sustaining productivity and benefits.

- Adoptions of timely and micro-level long time weather forecast appropriate agro-advisories to farmers are essential.
- In frost affected areas, promotion of short duration cultivars in place of long duration cultivars.
- In rainfed areas, conservation of rain water by *in situ* and *ex-situ* rainwater harvesting method and irrigation applied at drought conditions before flowering stage through drip or furrow or check basin or boarder strip method.
- Evolving varieties resistant/ tolerant to climatic stress of multiple biotic (eg. wilt, blight, pod borer, *etc*) and abiotic climatic stresses (eg. frost, drought, aberrant temperature tolerant, submergence, etc), through coordinated research efforts by public and private sector.
- For increasing yield, benefits,

energy savings and improving physico-chemical properties promoting resource conservation technologies such as permanent bed, conventional bed and ridge furrow sowing.

- More emphasis on need based area specific recommended abiotic and biotic stress resistant/tolerant varieties seed production through seed societies, farmers group with technical help of University personnels.
- Seed supply to end user along with bio fertilizers and with *Trichoderma* @ 10 g/kg seed for seed treatment.
- Formulate state specific weather based abiotic and biotic stresses insurance policies and encourage farmers for wider adoption for minimizing losses during extreme climatic events.
- Policy is formulated regarding the efficient utilization of natural resources, energy use, providing and availability of quality inputs in market and procurement of farmer produce on support price fixed by Government etc.
- Area specific impact of climate change adaptation should be critically examined.

SUMMARY

Appropriate area specific climate resilient technologies can help in coping up with the challenge of climatic variability. Some climate resilient technologies such as cultivation of drought, heat, insect pest resistant/tolerant cultivars, slight modification in crop management practices, adoption of water management technologies, conservation agriculture technologies and better pest management, access to weather forecast can help to increase productivity of pulse. The crop established on bed and furrow for irrigation increases productivity and saving of crop from more water submergence. Similarly, insurance policies promoted to combat and minimize losses during extreme climatic events. Some of these technologies for pulse production are already being practised by farmers in some parts of the country. But there is a need of wide dissemination and adoption of area specific technologies to protect or enhance pulse production. Thus it is concluded that timely adoption of proper technologies and tolerant/resistant cultivars can dilute effect of climatic abnormalities and doubling yield and benefits from rainy season pulse crops.

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Attracting and Retaining Youth in Agriculture (ARYA)

Realizing the importance of rural youth in agricultural development especially from the point of view of food security of the country, ICAR has initiated a program on "Attracting and Retaining Youth in Agriculture.

The objectives of ARYA project are:

(i) To attract and empower the youth in rural areas to take various agriculture, allied and service sector enterprises for sustainable income and gainful employment in selected district;

(ii) To enable the farm youth to establish net work groups to take up resource and capital intensive activities like processing, value addition and marketing; and

(iii) To demonstrate functional linkage with different institutions and stakeholders for convergence of opportunities available under various schemes/program for sustainable of youth.

ARYA project will be implemented in 25 states through KVKs, one district, 200-300 rural youth will be identified for their skill development in entrepreneurial activities and establishment of related micro-enterprise units in the area of Apiary, Mushroom, Seed processing, Soil testing, Poultry, Dairy, Goatry, Carp-hatchery, Vermi-compost etc. KVKs will involve the Agricultural Universities and ICAR Institutes as technology partners. At KVKs also one or two enterprise units will be established so that they serve as entrepreneurial training units for farmers. The purpose is to establish economic models for youth in the villages so that youths get attracted in agriculture and overall rural situation is improved.

The trained youth groups will function as role model for other youths and will demonstrate the potentiality of the agri-based enterprises which will help in improving their confidence levels and encourage them to pursue farming as profession, generate additional employment opportunities to absorb under employed and unemployed rural in secondary agriculture and service related activities in rural areas.

Pradhan Mantri Krishi Sinchai Yojana

This *Yojana* brings

- Per Drop More Crop.
- Inputs from MoWR and DOLR received.
- Increase in agricultural production and productivity and enhance farm income.