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Mitigating Adverse Climatic Conditions through Water Harvesting Tank in *Malwa* Region

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ABSTRACT: The activity of excavation of water harvesting tank in the individual farmer's field was extremely useful in arresting the runoff, bringing the fields into leveled condition through spreading of excavated soil in depressed area thus in avoiding even temporary water logging and reducing the chances of soil erosion. It also enhanced the water availability and allowed him to adjust the cropping sequence, including changing the timing of sowing, planting, spraying, and harvesting. This helped him to take advantage of the changing duration of growing seasons and associated heat and moisture levels to an appreciable increase in the crop productivity by turning the mono-cropped area into a multi-cropped/crop diversified area. The conjunctive use of ground and harvested surface water allowed him to alter the time at which fields are sowed or planted. It also helped the farmer to regulate the length of the growing season to better suit the adverse climatic conditions. These adaptation strategies helped the farmer and saved his crops from total failure and minimized losses compared to adjoining farmers.

Key words: Water harvesting tank, adverse climatic conditions, adaptation strategies

Introduction

It has been predicted that the change in climatic condition word wide may increase in extreme weather events such as floods, droughts, cyclones and heat waves which in turn will adversely affect agricultural productivity. Similarly, reduction in yields in the rainfed areas due to changes in rainfall pattern during monsoon season and increased crop water demand has been estimated. It has also been reported that incidence of cold waves and frost events may decrease in the future due to global warming and it would lead to a decreased probability of yield loss associated with frost damage in *Rabi* crops (Agarwal, 2007). In addition, degradation of soil and a decrease in water resources resulting from climate change have negative impacts on global agriculture (Anonymous, 2001a). Agriculture may be particularly vulnerable to climate change due to its dependence on natural weather patterns and climate cycles for its productivity. However, the adverse climate has been the pattern of Indian weather conditions and found to be affected, particularly rain-fed farming since long (Asha Latha *et al.,* 2012).

In *Malwa* region too, the early onset-late withdrawal, late onset – early withdrawal, prolonged dry spells, continuous wet spells, etc., have been the features of the monsoon (Table 1, 2 and 3). Frost like situations in January-March, untimely rains, windy – hail storms also being experienced in the region since long. The climatic conditions have never been almost normal or favourable enough particularly for both *kharif* and *rabi* crops from the point of view of higher production. The limiting and non limiting moisture conditions caused by inadequate and uneven distribution of rainfall continues to be the most important climatic aberrations, which influence the agricultural production in this region. This has been the climatic trend of the region earlier also like most of areas of India. Therefore, producing the different crops with satisfactory yield levels without total damage to crops grown even under adverse climatic conditions should be the adaptation strategies for rainfed production system (Vikas Kumar *et al*., 2015). Various studies (Agrawal and Narain, 1997, Ariyabandu, 2001 and Rana and Gupta, 2010) in other regions of the country showed a positive impact of rainwater harvesting on socioeconomic conditions. Recently, excavation of farm ponds on the individual farmer's field has been found extremely useful in turning the mono-cropped area into multi-cropped/crop diversified area in this region (Ranade, 2014).

Team of Operational Research Project for Dryland Agriculture, College of Agriculture, RVSKVV, Indore is involved with the farmers of the region and carrying out various scientific agricultural activities which may help the farmers to produce both *kharif* and *rabi* crops without any significant yield reduction even under very adverse climatic abrasions. Since soil and water management is highly critical for adaptation to climate change, the project made several attempts towards water conservation and water harvesting improvement in irrigation accessibility in the farmers' fields (Pathak *et al.,* 2011). To deal with the impact of climate change, an attempt was made to enhance the water availability by constructing various water harvesting through farmers participation and dove tailing activities. Further, technical guidance was also provided to the farmers for the creation of water bodies in the farmers' fields itself for improving water and rain water management. A huge water harvesting tank was developed in a village Mordhan (Khudel) district Indore in May 2007 under the technical guidance. The impact assessment study on various aspects of rainfed practices was made since then in the farmer's field after the increased water availability. The research experiences gathered is being reported for its wide scale adoption and developing site specific strategies.

Table 1 : Rainfall distribution recorded during the study period (2007-2014) in ORP area

Particulars	Details
Normal onset date of monsoon	15 June
Actual onset in 2007, 2008, 2009, 2010	15 June, 16 June, 27 June, 04 July
Actual onset in 2011, 2012, 2013, 2014	22 June, 02 July, 25 June, 10 July
Normal withdrawal date of monsoon	19 September
Actual withdrawal in 2007, 2008, 2009, 2010	30 Sept., 23 Sept., 09 Sept. 10 Sept.
Actual withdrawal in 2011, 2012, 2013, 2014	01 Oct., 10 Sept., 08 Oct., 10 Oct.
Average rainfall (mm)	941
Rains (mm) in 2007, 2008, 2009, 2010	0928, 0591, 1080, 1000
Rains (mm) in 2011, 2012, 2013, 2014	1584, 1022, 1633, 0877
Number of rainy days in 2007, 2008, 2009, 2010	40, 40, 47, 45
Number of rainy days in 2011, 2012, 2013, 2014	56, 31, 46, 31

*RD- rainy days.

Table 2 : Month wise Normal and actual rainfall recorded during 2007-2014

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
						Normal rainfall (mm)							
	9.3	4.1	1.6	2.3	17.4	147.2	243.7	325.8	140.9	31.9	13.5	3.1	941.0
						Actual rainfall (mm)							
2007	3.8	6.8	0.0	0.0	46.2	192.8	279.0	198.2	200.8	0.0	0.0	0.0	927.6
2008	0.0	0.0	0.0	0.0	0.0	149.0	90.8	232.6	93.0	16.0	7.2	2.0	590.6
2009	28.6	0.0	3.6	0.0	36.7	109.5	420.2	124.8	142.8	64.8	124.0	25.2	1080.2
2010	11.0	0.0	0.0	0.0	30.2	166.4	130.3	393.5	167.0	1.8	99.4	0.0	999.6
2011	0.0	0.0	0.0	0.0	9.2	104.2	465.4	916.5	72.9	16.2	0.0	0.0	1584.4
2012	0.0	0.0	0.0	0.0	83.7	34.4	466.7	268.2	168.9	0.0	0.0	0.0	1021.9
2013	0.0	17.9	5.3	0.0	6.1	358.8	636.8	372.1	136.2	99.8	0.0	0.0	1633.0
2014	55.6	42.2	0.0	0.0	24.2	11.0	372.6	171.6	163.0	31.4	0.0	5.8	877.4

Table 3 : Extreme events recorded during monsoon period

Year	Dry spell	High intensity rains (Date, rainfall in mm)
2007	Aug. 10-20 (11 days)	June 20 (51); June 30 (51), July 9 (111), Aug. 8 (59)
2008	July 13-25 (15 days) Sept.13-25 (15 days)	Aug. 26 (82)
2009	June 15-26 (12 days) Aug. 17-26 (11 days) Sept.7-Oct.3 (26 days)	June 29 (67), July 3 (92), July 22 (79), July 23 (108), Sept 4 (98)
2010	No rains after 11 Sept.	June 29 (64), Aug. 07 (106), Sept. 08 (65)
2011	-	July 09 (53), July 23 (108.4), Aug.21 (110), Aug. 24 (156), Aug. 27 (73), Aug. 28 (62), Sept. 01 (77), Sept. 02 (53)
2012	No rains after 13 Sept.	July 28 (135), July 29 (161), Aug. 07 (94), Aug. 08 (64), Sept. 06 (108)
2013	Aug31-Sept11 (12 days)	June 16 (72), June 26 (101), July 04 (234), July 27 (98), Aug. 02 (67), Aug. 24 (130), Sept. 21 (89)
2014	Aug. 08-24 (17 days)	July 24 (88), Sept. 08 (69)
Low temp (less than 30C) recorded		
2012	Jan.13 (2.5), Jan. 14 (2.0), Jan. 22 (2.0), Feb. 09 (2.5)	
2013	Jan. 08 (2.0), Jan.09 (2.0), Jan. 10 (3.0), Jan. 11 (3.0)	

Table 4 : Crop diversification and yield levels before and after availability of additional surface water in area of 25 ha

Season	Year				
	Before the tank 2006	After the tank construction			
		2007-08	2008-09 onward till 2014 every year		
kharif	Soybean (25 ha)	Soybean (25 ha)	Soybean (25 ha)		
Yield (q/ha)	10-12	18-20	18-20		
rabi	Wheat (3 ha)	Wheat (15 ha)	Potato (8 ha)	Wheat (8.5 ha)	Chickpea (8.5 ha)
Yield (q/ha)	30	60	450-500	70	18-20
rabi	Chickpea (8 ha)	Chickpea (10 ha)	Late wheat variety (8 ha) after harvest of potato		
Yield (q/ha)	8-10	18	50		
rabi	Other fallow				
	Pegionpea	Pegionpea on tank bund	Pegionpea on tank bund		
Yield (q/ha)	-	18-20	18-20		
		Vegetables in one ha area only for domestic purpose			

Materials and Methods

The study was initiated and undertaken in January 2007, in a farmer's field in Mordhan (Khudel) village of district Indore district (22°42'40" N latitude, 75°53'45" E longitude, 540 m MSL) representing the sub-watersheds on the Vertisol of Malwa plateau which is about 20 km from College of Agriculture, Indore. The average rainfall of the study area is 965 mm, whereas, the yearly rainfall ranges from 650 to 1321 mm.

It was observed that in this village, surface water and ground water is the major constraint for satisfactory crop production. The combined family of the farmer owns about 27 hectare land and is growing mainly soybean in *kharif* and chickpea and wheat in *rabi* since 1995. Eventhough many tubewells were constructed, the quantity of irrigation water received was not sufficient for the field under cultivation. It was clearly observed that the entire village was dependent on the rainfed farming practices. Even if the area gets good rainfall, the tubewells will yield up to December – January only. Therefore, despite owing sizable cultivated field, the farmer's family was not able to produce higher crop production. However, it was observed by the team of Operational research Project for Dryland Agriculture, College of Agriculture, Indore that due to topographical features of the area associated with monsoon rains in the region and inherent soil physical properties (soil is clayey in nature with higher runoff producing properties), there is lot of potential for developing huge water harvesting tank in the farmers field itself. It was also assessed that since the field is located by the side of national Highway, there are chances to store additional runoff coming from other areas too in the proposed water harvesting tank. Thus, it was suggested that for irrigating 25 hectare atleast twice or thrice in *rabi* season, a huge water harvesting tank of approximately (size 130 m x 100 m x 6 m and 70000 cu.m. storage capacity) be constructed in his field. It was estimated that for this purpose, an area of 1.5 hectares is required and the farmer has to spend approximately 10 lakh for the excavation and spreading of excavated materials into adjoining fields to make it leveled which are having several washes, undulating slopes due to continued runoff movement and soil erosion process within the fields. Considering all the prospects and aspects, the farmer readily agreed to provide one hectare land for this purpose and to bear the entire cost of developing the tank under the technical guidance of ORP team. Immediately, in March 2007, the excavation work was started using back hoe loaders machines and dumpers. The excavated soil was then spread into lower, undulating fields to make them in proper shape and size. The soil was also used to strengthen the existing entire farm road in the field. The work was completed in May 2007 with the development of water harvesting tank (size 130 m x 100 m x 6 m) in 1.5 hectare area with 68325 cubic meter storage capacity by investing approximately 11 lakh.

Since the natural outlet of the tank was located by the side of the highway, the same was utilized as the inlet for the tank so that after filling the tank the excess water flows out from the same drainage line. Thus, by keeping the common inlet and outlet of the tank, a sum of 50000/- were also saved. Immediately in the following monsoon of 2007, the tank was allowed to fill with the runoff water to the brim and huge amount of water was stored in it. Subsequently the stored water was utilized during dry spells in *kharif* and for pre-sowing and after sowing irrigation in *rabi* seasons. Since the constructed water harvesting tank is so located, it was observed that despite scanty or low rainfall year, the tank got filled to its full capacity i.e. 68325 cu.m. in year 2007 to 2008. However, since 2009 onward the renovated desilted tank was storing 85406 cu.m. of water every year. Even after the use of stored water in *rabi*, the tank was refilled by the tubewell water to enhance the conjunctive use of surface and ground water.

Results and Discussion

A close observation of the rainfall data (Table 1, Table 2, and Table 3) clearly shows that the region experienced erratic monsoon pattern for almost all the years (2007 to 2014). During this period, the rainfall was found to be deviated from the normal rainfall. It was also observed that the prolonged dry spells and continuous wet spells have also been experienced by the crops during the study period.

Changes in cropping pattern and crop diversification

Prior to the construction of water harvesting tank, the farmer used to grow soybean in 25 ha in *kharif* and chickpea and/or wheat in *rabi* only in a limited area depending on the availability of water from existing tubewells with low crop productivity. Prolonged dry spells during the rainy season was the main reason for the low productivity of soybean in *kharif*. Sometimes due to severe moisture stress, total failure of wheat was also reported. Earlier, the crops were adversely affected by frost, windy storm and untimely rains during winter season. Even total failure of *rabi* crops have also been observed in many fields either due to severe stress or/and adverse climatic conditions and non availability of sufficient irrigation water.

After construction of water harvesting tank (storage capacity 68325 cu.m.) in 2007, it was observed that in 2007-08, the farmer grew wheat in 15 hectare and chickpea in 10 hectare in *rabi* by utilizing the stored water as pre-sowing irrigation and the following irrigations as per the requirement of the crops. It was observed that due to storage of runoff water in the constructed water harvesting tank, entire area of 25 hectare was irrigated which was not possible with the existing tubewells. The farmer used both the submersible as well as diesel pumps for irrigation purpose from the tank. Therefore, despite the irregular electricity supply, by using both pumps could irrigate the entire 25 hectare land in sequence. This not only saved the time required for irrigating the field by 1/3 but also allowed the farmers to cultivate the entire field in time.

It was observed that generally in this region, the tube wells provide ground water with reduced discharge after the termination of monsoon season as ground water depletes at a faster rate due to over exploitation. Thus, very few tube wells operate throughout the year otherwise most of the tube wells go dry or supply water only for 2-3 hours that too with very reduced quantity. At the same time electric power supply is a deterrent in providing continuous irrigation to field crops. Sometimes the supply of tube well is so less that direct irrigation is not possible as a water advancement process does not take place, particularly in medium and deep clayey soils due to cracking pattern and irrigation process is not completed despite pump running for several hours. Therefore, tube well water was collected in the tank for few days in this case and then the stored water was used for irrigating the nearby fields using a high discharge diesel/electric pump so that a larger area can be irrigated at a time. During 2007, it was also observed that the farmer used this tank as storage tank even after utilizing the entire stored runoff for irrigation. He refilled the tank with tubewell water without using it directly to irrigate the field crops. It was also observed that since the percolation rates of the tank is very meager, the farmer is collecting tube well water in the tank for its utilization for raising even summer/vegetable crops. Thus, the farmer relied more on stored water in the tanks than the tube well water as most of the tube wells dry up suddenly/abruptly due to ground water depletion. Therefore, it was observed that the farmer not only got higher wheat production, but also increased the productivity with this additional irrigation water. In the year, 2007-08, itself, the farmer produced 900 q wheat and 200 q chickpea which was otherwise almost the double than the normal condition. Therefore, it was estimated that the farmer generated an additional income of ₹ 11 lakh with that additional and enhanced production of wheat and chickpea.

Introduction of new crop potato

The tank got filled with the runoff water in the month of June (storage capacity 68325 cu.m.) itself in 2008, as the runoff producing rainfall received in early monsoon. During *kharif*, the entire 25 ha area was brought under soybean cultivation with the combination of early and medium durational soybean varieties like JS 9560, JS 9305. Despite good initial monsoon condition, a dry spell in the month of August severely affected the soybean production in the adjoining fields. However, in the farmer's field, the harvested water in the tank provided life saving irrigation (3 cm) to entire 25 ha soybean crop which enhanced its productivity by 1.5 times than the other fields. A runoff event in the month of September 2008 again filled the tank. Encouraged by the availability of huge surface water in the tank and last year's experience, in 2008-09, *rabi* season, after providing pre sowing irrigations, a new crop of potato was introduced after soybean harvest by the farmer on the suggestions of project team. Improved varieties of Potato viz., Kufri lavkar, Chipsona, Kufri sindoori etc., were planted in different fields/plots in sequence as per the availability of field and its proper condition for sowing. In this year, the potato was sown in 7.5 hectare area. The other fields were sown with different varieties of wheat (GW-366, Lok-1, Harshita, Amrita, Pusa anmol, Pusa mangal, JW-17) and chickpea (JG-130, JG-16, JAKI-9218, JG-6, Vishal, JGK-3, KAK-2) crops in 8.5 ha each. After the harvest of potato in December, the fallow fields were once again sown with wheat crop of different varieties till January 2009 last week after pre sowing irrigations in each harvested field in the sequence (Table 4). Thus, all the fields were having wheat crop of different age, height and varieties. Thus, during 2008-09, after the harvest of soybean, the farmer produced a new crop of potato along with wheat and chickpea and all the field boundaries of the tank were sown with pigeonpea for the domestic purpose.

Desilting and deepening of tank

In 2009, further deepening of tank was carried out and the excavated clayey soil was spread in the adjoining cultivated field to fill up the depressions and to increase the soil fertility status. For this purpose, again 3 lakh was spent by the farmers. The renovated water harvesting tank was having dimension of 130 m x 100 m x 7.5 m with 85406 cu.m. storage capacity. This ensured proper drainage from the cultivated fields and even the chances of temporary water stagnation in it was avoided. Since 2009 onwards and till 2015 the farmer is growing continuously three crops in *rabi* season with higher productivity and thus ensuring a higher income level. Different varieties of wheat, chickpea and potato are being cultivated.

Minimized losses during adverse climatic conditions

In *Malwa* region, crop suffers from moisture stress towards the end of monsoon and it needs supplemental irrigation. The stored water (85406 cu.m) was utilized for providing life saving irrigation to a soybean crop during prolonged dry spells in 2009, 2011, 2013 and 2014.

In 2013-14, the soybean crop was damaged due to water logging in the fields of many farmers. However, the loss due to water logging was minimum in the selected field due to better drainage provision and proper leveling for the runoff collection in the water harvesting tank. Despite receiving higher rainfall than normal, 25 days dry spell during September 2013 compelled the farmer to provide life saving irrigation (3 cm) to long duration varieties of soybean and resulted in higher yield production. Thus, both the adverse climatic conditions like water logging in the initial stage and moisture stress towards the end of monsoon was successfully tackled without any appreciable loss in crop yield. Similarly, during *rabi* season the untimely rains, frost and hailstorm affected the crop productivity in other fields. In this 25 ha area, after the potato harvest, different fields were cultivated with wheat and chickpea (Figure 1) at different time intervals by providing pre-sowing irrigations in sequence (Figure 2). Therefore, at the time of untimely rains, frost and hailstorm, the height and age group of crops was totally different in various fields (Figure 3) and hence minimized the adverse effects of climate on crop productivity. Even at the time of harvest the untimely rains damaged the harvested wheat crop more than the standing crop in the field. A combination of wheat crop in different stages *viz.,* manually harvested wheat in bundles, wheat ready to harvest and wheat still in grain forming stage (Figure 4) in the same field was possible only due to enhanced water availability which ensured adjusting the cropping sequence, including changing the timing of sowing and planting. Thus the adverse impact of untimely rains and windy storm on crops was minimized and total failure of wheat was not observed in selected farmer's field.

Effect of deep ploughing

It was also observed that infestation of deep rooted fields, particularly Kans (*Sacchaurum spontaneum*), gajar grass (*Parthenium* sp) and mustard was very common in this region. The fields are, therefore, deep ploughed by the farmer using a tractor drawn reversible mould board plough initially provided by the project in 2007-2008. Encouraged by the result, the farmer himself purchased one tractor drawn reversible mould board plough and deep ploughing his fields once in a three year. This practice reduced the weed infestation and increased the soil

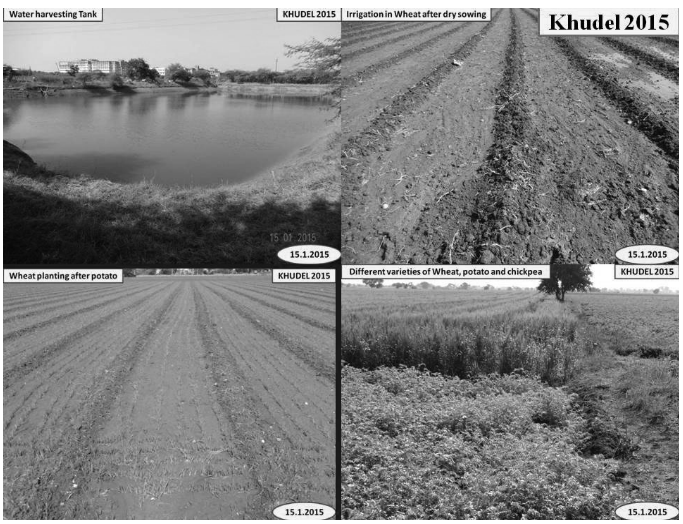

Fig. 1 : Rabi planting on different dates using harvested water in 2015

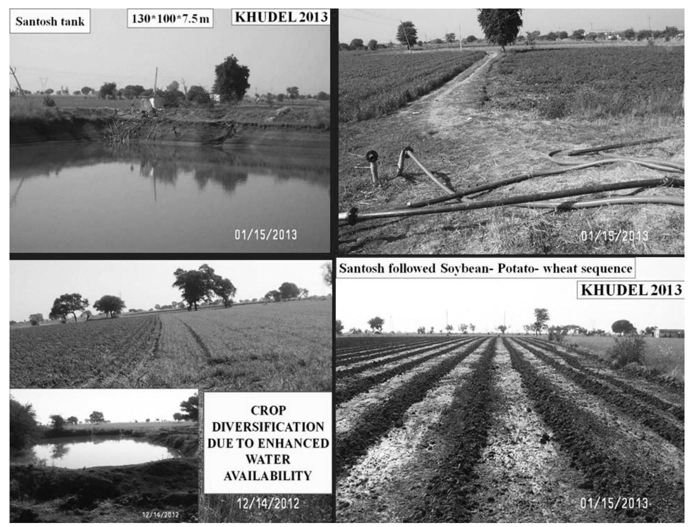

Fig. 2 : Crop diversification due to enhanced water availability in 2013

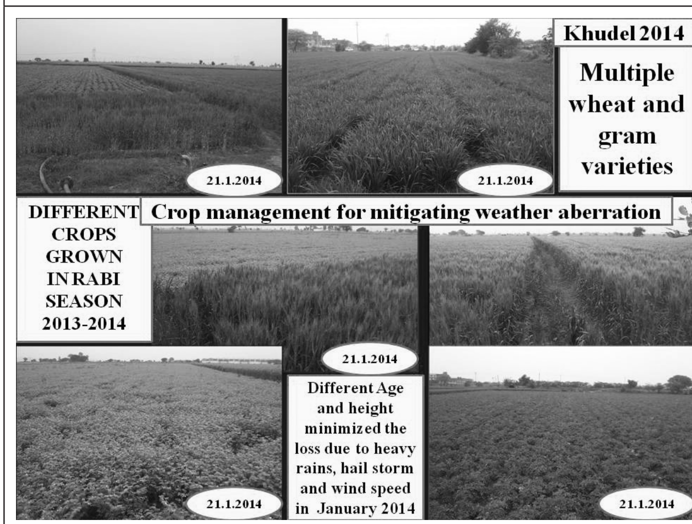

Fig. 3 : Multiple wheat and chickpea in the field

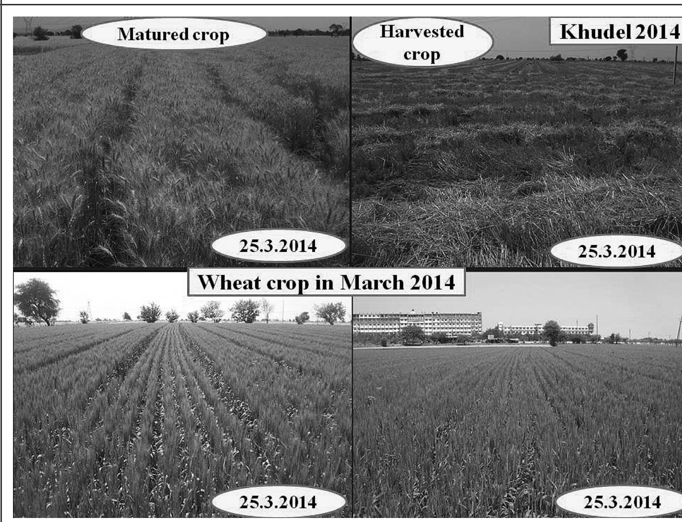

Fig. 4 : Wheat crop with different stages in 2014

moisture profile which in turn reduced the runoff and chances of water logging and further damage to crop. Similarly, the expenditure towards the weedicides was reduced by one third and breaking of hard layers below the root zone ensured better and bold size of potato in deep ploughed fields than unploughed fields. This practice improved the soil environment and ensured better germination of rainfed crops. Because of increased *in situ* moisture conservation, sowing of *rabi* crops was satisfactory without pre-sowing irrigation. The deep ploughing also reduced the frequency of irrigations and saved precious irrigation water for its further use. It has been experienced by many researchers that deep tillage is another viable option to increase productivity mainly due to enhanced *in situ* moisture conservation in addition to providing the salutary condition for crop growth (Bussacher *et al.,* 2000). Deep tillage was also found to contain weeds, which are instrumental in lowering the productivity of crops by way of offering severe competition to crop plants for natural resources (Muniyappa *et al.*, 1986, Tiwari *et al.*, 1997 and Ranade and Verma (2007).

Agronomical practices followed to address climatic adversities

Crop diversification adopted by the farmer after the construction of tank increased the cropping intensity and enhanced the income of the farmer. Introduction of potato in the cropping system provided an opportunity to cultivate wheat and gram in December-January month. The delayed sowing saved these crops from getting adversely affected due to high September-October heat in the early crop stages and due to low temperature during reproductive phase. The farmer followed crop rotation for saving the crops from fungal and bacterial infections. Intercuture operation during dry spells in *kharif* reduced the infestation of weeds and conserved the soil moisture. Different potato planting systems *viz.,* one row and two rows planting on raised bed-furrow with introduction of drip irrigation system enhanced the irrigation water efficiency. Due to enhanced water availability, the farmer is now irrigating the crops during occurrence of frost instead of traditional temperature increasing system of burning straw all around the fields.

Introduction of micro irrigation system

On the insistence of the project team, the use of drip irrigation system for growing potato by farmer resulted in higher irrigation efficiency and higher crop production. The rain gun and sprinkler irrigation systems were also utilized by the farmer for irrigating wheat crop and sometimes sprinkler for irrigating soybean during dry spells. Thus, increased water availability encouraged the farmer to adopt crop diversification practices and motivated him to adopt micro irrigation for higher efficiency and water saving. But it is very clear that in *Vertisols* of this region, better *rabi* crop germination and growth can be ensured only by providing flood irrigation through border method before or after the sowing. For the subsequent irrigation, sprinkler irrigation can be used.

Even the use of *Livocin*, a growth regulator restricted the unnecessary biological growth in wheat and strengthened the roots. Hence less damage was observed during adverse climatic conditions like untimely rains, hailstorm and frost due to reduced chances of damage by lodging. Therefore, overall damage in comparison to other farmers was comparatively less and almost 1.5 times more yield was recorded in wheat crop.

Thus, in the present study, the adjustment in the cropping sequence, including changing the timing of sowing, planting, spraying, and harvesting, which was possible due to enhanced water availability helped to take advantage of the changing duration of growing seasons, associated heat and moisture levels. Altering the time at which fields are sowed or planted helped the farmer to regulate the length of the growing season to better suit the adverse climatic conditions. Farmer adaptation practices involve changing the timing of irrigation and use of other inputs such as fertilizers.

Conclusions

It can be, thus, concluded that due to increased water availability through the development of water harvesting tank, many adaptation strategies viz. Introduction of tolerant cultivars resistant to temporary water logging and drought, modifying crop management practices, improving water and rain water management, adopting new farming techniques such as crop diversification, particularly to deal with the impact of climate change could be adapted successfully to minimize the damage to crops due to adverse and changing weather conditions. Therefore, increasing irrigation water availability through water harvesting tank could be a successful way to mitigate adverse climatic conditions in *Malwa* region. Since soil and water management is highly critical for adaptation to climate change, attempts towards water harvesting, improvement in irrigation accessibility and water-use efficiency should be made on priority basis. At the same time, the farmers have to be motivated for adopting on-farm water conservation techniques, micro-irrigation systems for better water-use efficiency, selection of appropriate crops, etc.

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