Opportunistic agroecological adaptation by farmers under semi-arid conditions of Rajasthan, India

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Abstract

Climatic vulnerability and multiple stressors have compelled small-holder farmer world over to develop location specific knowledge and adaptation strategies to sustain their livelihoods in risk-prone ecosystems. Under these conditions local farmers face of high temperature, hot and dry winds, low and delayed monsoon, high salinity in ground water, erratic rainfall and early recession of rains. The farmers of arid zone store runoff water in catchment area and effectively utilize the conserved soil moisture for crop diversification under varying moisture regimes. This opportunity is now adapted with introduction of muskmelon or cantaloupe a fruit vegetable relished for its taste and sweetness. In the land, freed from water, grows muskmelon in the conserved moisture during last week of February. This adaptation is continued when there is very minimal competition with other agricultural enterprises. Based on the 3 years study, observed that muskmelon grown with adequate irrigation supply and with high inputs recorded significantly higher growth and yield parameters, fruits yield as well as delayed in flowering and maturity as compared to conserved moisture with low inputs. There was no significant difference were observed in the overall profitability among muskmelon cultivation conditions. The conserved moisture with low inputs recorded higher benefit cost ratio. This location specific agro-ecological adaptation empowers other farmers, who are landless and relatively more marginalized. It also provides an insight for the formal science about how formal and informal knowledge can be hybridized to co-produce more robust adaptation to convert stressors into opportunity.

Introduction

The arid western part of Rajasthan state (2,11,867 km^2), encompassing a major part of the Thar or the Great Indian Sand Desert, is dominated by sand dunes, sandy plains of variable thickness (some being salt-affected), as well as some barren hills, uplands and gravelly pavements (Santra et al. 2013). Mean annual rainfall in the region varies from about 500 mm along the slope of the Aravallis in the east to 100 mm along the border with Pakistan in the west, more than 85% of which is received during the period of South West monsoon (June-September). High summer temperature (often reaching 50ºC) and very low winter temperature (sometimes below 0ºC), with large diurnal and spatial variability, as well as high wind speed between March and July with speed gusts of > 50 km/h during dust storms, are the other major climatic characteristics (Sen and Gupta 1982). The mean annual potential evapo-transpiration exceeds precipitation by a wide margin (1400–2000 mm). Between 1801 and 2002, this area suffered from 42 serious droughts that reduced agricultural production (Saxena and Mathur 2019). In early 2013, parts of western India were suffering from the worst drought in more than 40 years. The area is dominated by small-scale farmers, especially poor subsistence farmers which loath to take risks, they cannot afford to. If a gamble does not pay off and in the context of uncertain physical and financial climates, investing in improved seeds, fertilizers and other inputs is a gamble (Varghese and Singh 2016; Singh et al. 2020). The farmers and their livestock in arid zone are always at risk. In this circumstances farmer of this area generally perform farm activities which are time and labour intensive, monotonous and more drudgery prone. Therefore, a paradigm shift in farming practices through eliminating unsustainable parts of conventional agriculture (ploughing/tilling the soil, removing all organic material, monoculture) is crucial for future productivity gains (Jackson et al. 2004). The high biotic pressure on the arid lands aggravates the desertification process and reduces the productivity of crops, which results in over-exploitation of resources of the region (Gupta and Narain 2003). The per capita availability of land is consequently decreasing; while food and fodder demand is increasing. Sustainable crop production is thus a major concern to meet the food and fodder requirement under such circumstance. Conservation agriculture, a concept evolved as a response to concerns of sustainability of agriculture globally, has steadily increased worldwide to cover about ~ 8% (124.8 M ha) of the world arable land (FAO 2012). Soil moisture conservation is a resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with three interrelated principles, along with other good production practices of plant nutrition and pest management (Abrol and Sangar 2006). Crop failure is a common feature either due to inadequacy of rainfall or due to shortage of soil moisture to meet the crop water requirements during different phenophases (Barnabas et al. 2008). Besides this, the arid region has several biotic and abiotic limitations that are responsible for low productivity. Under these conditions local farmers utilized agroecological knowledge to convert stress into opportunity with autonomous adaptation. The objective of this paper is to review the salient results of soil moisture (in-situ) conservation technologies for increased land productivity and improve livelihood security in the western arid region of Rajasthan (India).

Material And Methods

Site details

The Rajasthan state is the first largest state of Indian union covering an area of 3.42 lakh sq. km. It lies between 23.290 and 30.120 North latitude and 78.170 East longitudes bordered by Pakistan on the west and states of Gujarat, M.P., U.P., Punjab and Harayana. The present study ware conducted in two different agro-climatic conditions the first site was conserved moisture with low input (CMLI) situation (Hemawas dam catchments area, which is located on {25.7343^0 North latitude and 73.3620^0 East longitudes} the Bandi river of Pali district) and second site was Adequate Irrigation with high inputs (AMHI) situation (Naya Gaon village Sojat Tehsil {25.9238^0 North latitude and 73.6651^0 East longitudes} Pali District), both sites falls in the arid zone of western Rajasthan (India). The climatic conditions near Hemawas area are marginally different from the typical arid western Rajasthan and the area had sub-mountainous and has undulated plains with scattered hills here and there. Although, basically the summer season raises the temperature to 46–47°C during peak (May-June) months, a large variation in temperature is found due to adjoining green and hilly areas. Winters are moderately cool during December-January when the mercury dips to 4–5°C range. Monsoon brings respite from long drawn summers and the rains during the months of July-October result into average rainfall of 450.7 mm in the district. During the monsoon period relative humidity is high varies from 60–80%. The summer months are driest when humidity varies from 20–30%. The both area produces traditional crops like bajra, guar, sesame and pulses in the kharif season. In the rabi season wheat, barley, mustard and vegetables are the dominant crops. The soils are yellowish brown with sandy loam to sandy clay texture; it is suitable for cultivation but low rainfall and high evaporation. In this area crop failure is a common feature either due to inadequacy of rainfall or due to shortage of soil moisture to meet the crop water requirements during different phenol phases. Besides this, the arid region has several biotic and abiotic limitations that are responsible for low productivity (Faroda et al. 2007).

Agroecological practices follow in first site (CMLI)

In first site during rains the dam becomes its full capacity and it is not possible to take any crop. Gradually after the rains the water level in the pond declines very fast due to seepage loss and utilization of water by the farmers to raise winter season crops. By the month of October ending a big proportion of pond land at higher level is available for raising rabi crops due to subsequent drying of water in the pond and only the deeper part of pond retains water. The farmers of this area utilize the available water for irrigating the crops as the result, more and more area becomes available for cultivation due to utilization of water stored in the deeper parts of pond. When the water in dam is dry or near to empty (Early December) many farmers utilizes the available or conserved moisture for raising different crops and vegetables. Under these conditions local farmers utilizes agroecological knowledge to convert stress into opportunity with autonomous adaptation by cultivation of short duration crop muskmelon. In adaptation the field is first ploughed two times to break hard pan, big soil clods and making proper soil tilth. Proper soil tillage is a prerequisite for good crop stand, growth and yield. Excessive tillage, particularly in light textured soils, disintegrates clods and exposes soil to wind and water erosion. Reduced tillage implies economy in time, labour and energy besides reduced soil moisture losses, maintenance of soil structure and increased cropping intensity (Saxena et al. 1997). The indigenous variety (KAJRI) seed of musk melon is used for sowing after seed treatment. The farmer made pit hole of 4–6 cm size at a distance of 6 feet row to row and 1-1.25 feet plant to plant. In each pit 4–6 treated seeds are sown and covered by sand. After 5–6 days when the seeds germinate, the farmer covers the seedlings in early stage by local available plants namely C*rotalaria burhia* and *Leptadenia pyrotechnica* for moisture conservation and checking the loss of evaporation. The seeds germinate fast and utilize the runoff organic matter and conserved moisture for luxurious growth and high yield when plant attains 10–15 cm a light ploughing of soil is done to conserve the soil moisture and controlling the sucking insects by burying the eggs deep and sealing the soil. After this operation the plants attain luxuriant growth and row plant overlap each other conserving moisture which is sufficient for its full growth and development till the maturity (The stepwise conservation practice is shown in Fig. 1). The main actor in the entire operations of the muskmelon's cultivation where either they contribute as family labour or as daily paid laborer earning cash from land owners.

Agroecological practices follow in second site (AMHI)

In second site field was prepared for sowing of seed using conventional tillage in early February. Recommended dose of fertilizer ware applied before final levelling. For sowing of seed beds were prepared measuring 2.0 m wide with two rows per bed and row to row 120 cm and plant to plant 30 cm spacing was maintained. The 2nd week of February of each year was time of sowing of both sites and it sown at a depth of 1–2 cm with 1 seed per hill. At the time of sowing Furadon (Carbofuron) @ 5 kg/ha was placed at the base of seed in order to prevent attack of insect pests especially red pumpkin beetle. Seed germination took about 5–7 days and after 30–35 days after sowing, a preventive spray with Mancozeb 75% W.P. @ 1250g/ha was applied at interval of 7–10 days repeatedly. Irrigation was applied in furrows as and when required, generally it may be given @ 10 days intervals to maintain moisture. A continued watch was kept on the growth, disease incidence appearance and improved cultivation management ware followed.

From each location, five average size muskmelon plant and fruits were selected in each year (2017, 2018 and 2019), and data were recorded on different parameters namely length of vine (m), number of leaves per vine, days to first flowering, days to first female flowering, days to first harvest, number of fruits per vine, fruit weight (g), fruit yield per vine (kg) and fruit yield (t/ha) and economics were calculated on the basis of cost of cultivation and price of fruit prevailing during the period. The benefit cost (B:C) ratio were calculated by dividing the absolute net return and costs of cultivation, while the productivity per day (Kg/ha) and total yield per day (Rs/ha) were translated by total yield and total net return per days, respectively up to crop duration. The data was analyzed by using OPSTAT (OP et al. 1998).

Result And Discussion

In this paper traditional cultivation practices of muskmelon using conserved moisture with low inputs (CMLI) situation have been compared with the muskmelon cultivation by applying all required inputs as adequate irrigation with high inputs (AMHI) situation. The study results revealed that irrigation management practices with input levels significantly influenced the growth parameters, flowering behavior, yield parameters and yield of muskmelon. Application of adequate irrigation with high inputs like intensive tillage, fertilizers, plant protection measures etc. contributed to higher growth parameters of muskmelon crops *viz.*, length of vine (Table 1) which was significant difference observed among the both situations of cultivation in all three years and its mean (varied from 1.78 m to 2.18 m). The significantly maximum number of leaves per plant (Table 1) reveled in adequate irrigation with high inputs (AMHI) cultivation site in all three years as well as in mean as compared to crops sown under conserved soil moisture condition with lower amount of inputs (CMLI). Based on 3 years mean a significant delay was observed with regard to days to first flowering (35.4 DAS), days to first female flowering (40.0 DAS), days to first harvest (91.1 DAS) and longer crop duration (132.0 days) for the crops subjected to irrigation water with high inputs as compared with the crop under conserved soil moisture with low input (CMLI) condition.Thus, crop sown under conserved soil moisture condition with lower amount of inputs were early with regard to days to flowering (29.7 DAS), days to first female flowering (34.1 DAS) and also produced early marketable fruits (Table2) or days to first harvest (82.4 DAS). The increase in growth parameters, delayed flowering and fruiting was attributed to regular sufficient supply of soil moisture and inputs under irrigated conditions. The adequate and timely supply of irrigation, nutrition, weed and insect pest management lead to improve availability of nutrient that enhanced proper growth and development of plants in all three years, respectively. Minimizing the competition of crops with biotic and abiotic stress free conditions also resulted in higher growth parameters of plant, as compared to conserved moisture crops with low inputs (CMLI). These findings are in close conformity with the findings of many researchers in different crops (Anbumani et al. 2017; Al-Majali and Kasrawi 1995; Ban et al. 2004; Patil et al. 2014; Ansary and Roy 2005).

Table 1
Effect of agronomic management practices (Adequate irrigation with high inputs (AMHI) and Conserved moisture with low input (CMLI)) on growth parameters of muskmelon

Agronomy management Practices	Length of vine (m)				Number of leaves per vine				Days to first flowering (DAS)				Days to first female flowering (DAS)			
	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	2019	Mean
CMLI	1.70	1.82	1.82	1.78	70.4	69.4	67.9	69.2	30.2	29.8	29.2	29.7	34.1	34.3	34.0	34.1
AMHI	2.08	2.13	2.32	2.18	79.9	79.7	80.4	80.0	35.0	35.6	35.6	35.4	39.7	40.2	40.0	40.0
C.D.	0.25	0.13	0.16	0.15	6.2	4.3	5.3	4.8	2.1	1.7	1.5	1.4	2.1	1.4	1.6	1.4
SE(m)	0.08	0.04	0.05	0.05	1.9	1.3	1.6	1.5	0.6	0.5	0.5	0.4	0.6	0.4	0.5	0.4
C.V.	12.69	6.3	7.7	7.1	8.1	5.6	6.9	6.3	6.2	5.0	4.5	4.2	5.5	3.7	4.3	3.6

Table 2
Effect of agronomic management practices (Adequate irrigation with high inputs (AMHI) and Conserved moisture with low input (CMLI)) on yield parameters of muskmelon

Agronomy management Practices	Days to first harvest (DAS)				Crop duration (DAS)				Number of fruits per vine				Fruit weight (g)			
	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	2019	Mean
CMLI	83.7	82.8	80.5	82.4	116	114	113	114	12.0	12.5	12.8	12.4	348.9	349.2	344.6	347.4
AMHI	91.5	92.6	89.2	91.1	133	132	130	132	14.9	14.7	14.7	14.7	395.6	403.7	373.8	391.1
C.D.	3.2	3.2	2.3	2.6	2.6	4.8	1.4	2.2	1.0	0.9	1.0	0.8	23.2	18.2	23.6	17.6
SE(m)	1.0	1.0	0.7	0.8	0.8	1.5	0.4	0.7	0.3	0.3	0.3	0.3	7.2	5.6	7.3	5.4
C.V.	3.5	3.6	2.6	2.9	2.0	3.8	1.1	1.7	7.3	6.1	7.1	5.9	6.1	4.7	6.4	4.6

The data also revealed (Table 2) that the adequate irrigation supply coupled with high inputs (AMHI) significantly increased the growth parameters of muskmelon and also increase crop duration (132 DAS), number of fruits per vine (14.7), fruit weight (391.1 g) and fruit yield per plant (5.77 kg) as compared to conserved soil moisture crops with low inputs (CMLI). It was due to availability of sufficient soil moisture which increase vegetative growth and higher uptake of nutrients to the crop throughout the growth duration for better growth and development of fruits. The results indicate that fruits yield per hectare of muskmelon recorded significantly higher with adequate irrigation with high inputs (96.2 t/ha) as compared to conserved soil moisture practices with lower inputs (71.99 t/ha) and increased by 25.16% higher as compared to conserved moisture practices. The higher number of fruits per plant and fruit weight was due to combined availability of soil moisture with proper nutrition throughout the muskmelon growth period. The above results are close conformity with the various reporters in other crops (Anbumani et al. 2017; Ansary and Roy 2005; Johnson et al. 2000; Arancibia and Motsenbocker 2008; Rani et al. 2012).

The irrigation management practices with agronomic inputs level were significantly influenced the profitability of muskmelon crops (Table 3). The mean of three years of adequate irrigation application combined with high production inputs increased the cost of cultivation that recorded the significantly higher gross returns (Rs. 5,28,070/ha) and net returns (Rs. 3,48,220/ha) compared to the conserved soil moisture practices with low inputs-based muskmelon cultivation. Also, similar trends were observed in the productivity per day (731 kg/ha) and net returns per day (2,646 Rs/ha) in all studied years and its mean, but the mean of Benefit cost ratio significantly highest were recorded with conserved soil moisture practices with low inputs (3.64) as compared to adequate irrigation with high inputs management practices (2.94). It was mainly due to early crop in market farmers get premium price compare to late crop produce in irrigated management and high input practices. Thus, the above results clearly reveal that muskmelon cultivation under stress conditions in this area is very profitable due to soil moisture conservation practices and hot and dry humid conditions with low temperature in night was favorable for its sweetness and its quality attributes. The market prefers the muskmelons grown under conserved moisture conditions and they are paid premium prices for their crop due to earliness. Irrigation practices often aims at total replacement of culture evapotranspiration in order to obtain maximum yield (Holzapfel and Mariño 2008). In many occasions experiments demonstrate that is possible to reduce water use without significant losses in yield. In addition, the increases in health, quality related compounds and postharvest preservation are evident in response to environmental stress. The use of regulated stress (water stress, salinity, heat) is a feasibly strategy to enhance accumulation of health promoting compounds in food. Another interesting perspective is the improvement of plant resistance against biotic stresses (e.g., pests and diseases) when submitted to controlled abiotic stresses, as was scientifically demonstrated in experiments utilizing different fruit and vegetable crops (Nora et al. 2012).

Table 3
Effect of agronomic management practices (Adequate irrigation with high inputs (AMHI) and Conserved moisture with low input (CMLI)) on yield and profitabi
muskmelon

Agronomy management Practices	Fruit yield per vine (kg)				Fruit yield (t/ha)				Gross returns (Rs.)				Net returns (RS.)		
	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	20
CMLI	4.19	4.37	4.41	4.32	69.75	72.77	73.46	71.99	418517	472978	514219	468572	295017	342528	38
AMHI	5.88	5.93	5.51	5.77	97.89	98.84	91.86	96.20	489448	543617	551145	528070	312598	363417	36
C.D.	0.41	0.42	0.52	0.42	6.77	7.03	8.62	6.91	36766	42069	NS	40727	NS	NS	N
SE(m)	0.13	0.13	0.16	0.13	2.09	2.17	2.66	2.13	11332	12967	16759	12554	11332	12967	16
C.V.	7.9	8.0	10.2	8.0	7.9	8.0	10.2	8.0	7.9	8.1	9.9	8.0	11.8	11.6	14

Table 4
Effect of agronomic management practices (Adequate irrigation with high inputs (AMHI) and Conserved moisture with low input (CMLI)) on profitability parameters of muskmelon

Agronomy management Practices	B:C ratio				Productivity per days (Kg/ha)				Net returns /day (Rs/ha)			
	2017	2018	2019	Mean	2017	2018	2019	Mean	2017	2018	2019	Mean
CMLI	3.39	3.63	3.88	3.64	600	642	654	631	2539	3342	4055	2980
AMHI	2.77	3.02	3.02	2.94	734	751	708	731	2344	2385	2841	2646
C.D.	0.27	0.30	0.34	0.27	54	71	NS	59	NS	424	487	NS
SE(m)	0.08	0.09	0.11	0.08	17	22	22	18	92	131	150	107
C.V.	8.4	8.8	9.7	7.9	7.9	10.0	10.4	8.4	11.9	14.4	13.8	12.0

Conclusion

Thus, this in-situ moisture conservation practice or location specific agro ecological adaptations not only conserve moisture but also maintain soil fertility. This adaptation provides an insight for the formal science about how formal and informal knowledge can be hybridized to co-produce more robust adaptation to convert stressors into opportunity. The farmers having land at scattered site in Hemawas dam which is used to store runoff water in catchment area of around 260 hectares of land. The farmer very effectively utilized the conserved soil moisture in Hemawas dam catchments area for cultivation of muskmelon rather than traditional crop like wheat, barley, mustard and chickpea which have low yield and less return.

Abbreviations

AMHI: Adequate moisture with high inputs; CMLI: Conserved moisture with low inputs; DAS: Days after sowing.

Declarations

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Compliance with Ethical Standards

Conflict of interests

The authors declare that they have no competing interests.

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Figures

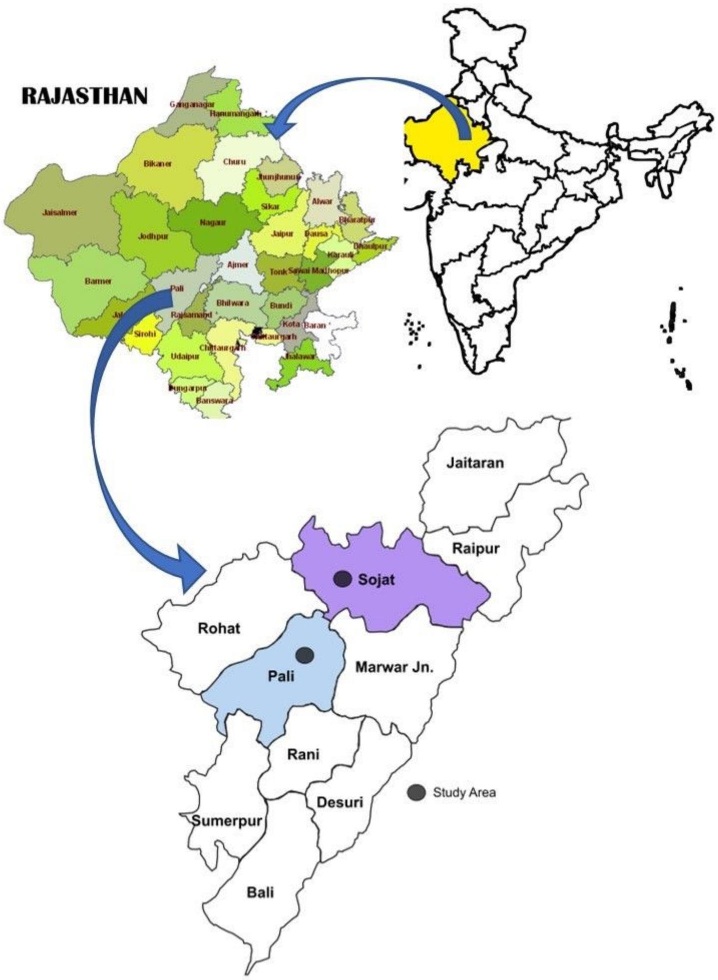

Figure 1

Location map of the study area

Figure 2

Step wise muskmelon cultivation practices in conserve moisture conditions (CMLI).

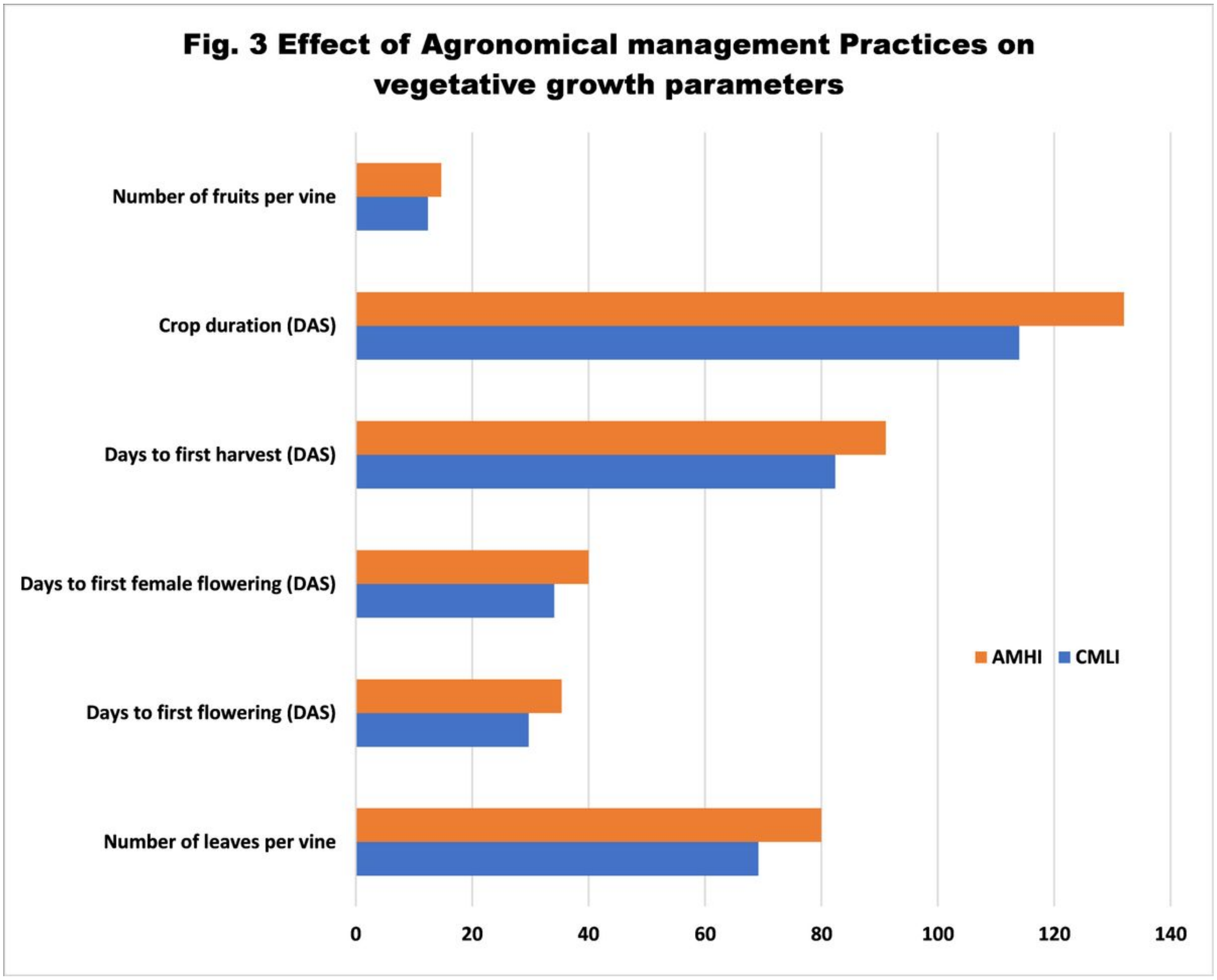

Figure 3

See image above for figure legend.

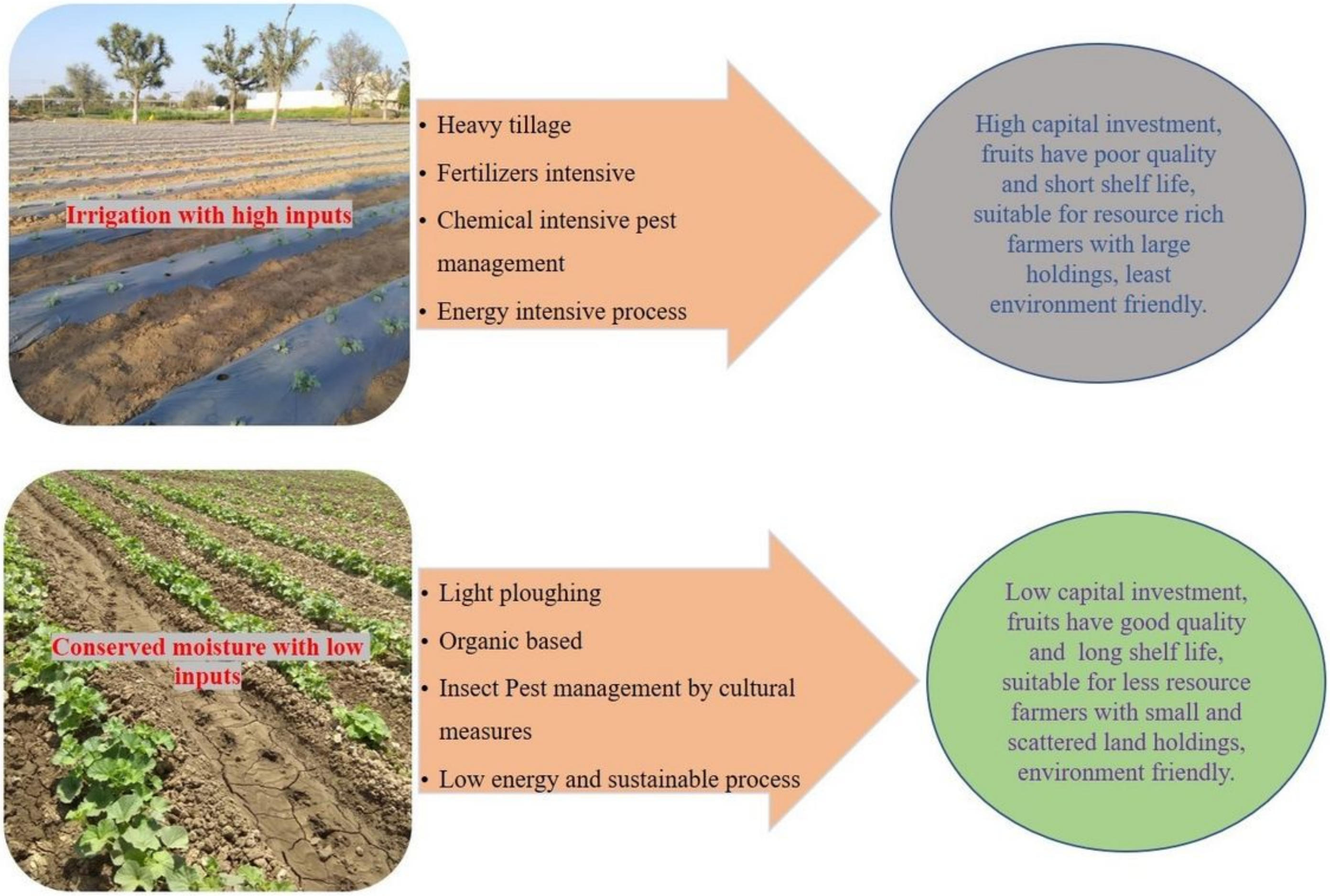

Figure 4

summarized the effect of location specific agro-ecological adaptations