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Impact of interspace managements on performance of bael in degraded lands of Chambal ravine

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ABSTRACT

The present investigation was conducted during 2007 to 2015 to evaluate adaptability and production potential of bael in degraded lands of Chambal ravine. The experiment was conducted using a randomised block design, including four interspace managements: clean tilled, clean tilled with half-moon, half-moon with *Cenchrus ciliaris* and half-moon with *Dicanthium annulatum* with three replications. The findings revealed that various interspace managements used during the experiment had a significant impact on growth, yield and quality parameters. Among the four interspace managements, clean tilled with halfmoon measure resulted in higher vegetative growth parameters as well as yield and quality attributes. In terms of mean yield, the highest fruit yield (6.10 t ha^{-1}) and B:C ratio (2.19) was recorded under clean tilled with halfmoon treatment (T_2). Therefore, bael (*Aegle marmelos)* is not only highly suitable but also remunerative fruit for conservation horticulture in degraded ecosystem of Chambal ravines on long term basis.

1. INTRODUCTION

Degraded ecosystems face depletion of flora and fauna and loss of productivity due to various abiotic and biotic disturbances resulting in slow recovery during natural succession of vegetation (Parandiyal *et al.,* 2020). It requires an integrated approach for soil and water conservation (SWC) measures and putting the land under permanent vegetation involves afforestation, agroforestry, horticulture, pastures. Selection of species of trees / shrubs / grasses is most important in ravine rehabilitation (Parandiyal *et al*., 2018).

Indian native fruit *bael* (*Aegle marmelos*) is an under utilized fruit crop. It is a member of the family Rutaceae and is also referred to as *maredo, bilva, Indian quince, holy fruit, bel, golden apple, belwa, sriphal* and *Bengal quince* in India. *Bael* is a subtropical fruit crop that can grow up to 1,200 metres above sea level and is unaffected by temperatures as low as -7°C. Although it is supposed to thrive best in fertile, well-drained soil, it also grows well and bears fruit even on limestone in southern Florida and also thrives in dry forests on hills and plains. It also flourishes well on alkaline, rocky or swampy soils with a pH range of 5 to 10 (Saroj *et al*., 2006). To bear fruit, this tree needs a distinct dry season. It can survive in all the conditions where other fruit trees can't drive.

To exploit the plant's therapeutic benefits, several plant parts (barks, leaves, roots, fruits and seeds) have been included in ethno medicine. The refined components of bael are biologically active against a number of serious diseases and it is a key component of many traditional formulations for treating a variety of diseases because of abundant bioactive substances present in the fruit. The demand for functional foods and natural antioxidants is expanding quickly on a global scale nowadays. Bael can play a significant role in the form of fortified value-added goods and functional foods (Singh *et al*., 2020). Several value added products are prepared from bael such as squash, murabba, jam, toffee, powder, fruit slabs etc. It is a widely distributed plant that can be found in China, India, Ceylon, Nepal, Bangladesh, Myanmar, Pakistan, Thailand, Vietnam, Laos, Cambodia, Malaysia, Tibet, Sri Lanka, Java, the Philippines and Fiji. Although bael is a subtropical fruit crop, it has a wide range of adaptation and may thrive in rainfed hot, semi-arid climates. India is leading in the world for bael production, area and productivity. Typically, it is planted as a boundary plant, in the premises of temples or in backyard gardens. In some natural forest the seedling plantations can also be seen.

! Recently, a few progressive farmers in Rajasthan, Chhattisgarh, Madhya Pradesh, Gujarat and Punjab have started cultivating bael on a large scale as orchards or as boundary plantations using improved cultivars. The improved varieties of bael is being planted in about 8000 ha of land nationwide, with the production of around 70,000 tonnes (Singh *et al*., 2021). Among the different cultivars NB-5, NB-9, Goma Yashi and CISH-B1 have covered nearly 90% of the land in various states of the nation. The sustainable exploitation of natural resources and their conservation are major concerns for the global community. Land degradation is a genuine ecological issue and requires urgent attention for sustainability of agriculture and economic development. A sizable portion of India (about 157 M ha) is categorised as different forms of degraded land, where one or more limiting factor(s) make crop cultivation economically unviable. Some underutilized fruit tree-based land use systems have been approved as an alternative land use option for degraded areas in India as a result of the tireless efforts of pioneer workers in the field (Pathak and Pathak, 2000). The higher runoff along with soil and nutrients during monsoon period and soil moisture deficit during critical growth stages in post-rainfall induces poor growth, yield and mortality of the plants in Chambal ravine regions. Hence, improvement of soil moisture status in plant basins during post-rainfall period through adoption of efficient conservation practices is necessary to enhance the productivity and to reduce the mortality in this water scarce region. The water availability for crop production can be improved through various soil water management practices. The interspace managements through rain water *in-situ* conservation would give the possibilities of setting up of new ecological system and whereby ameliorate local environments in the semi-arid regions (Li *et al.,* 2002). Badhe and Magar (2004), Khola and Sastry (2005), Manivannan and Desai (2007) and Samant *et al.* (2016) demonstrated that *in-situ* rainwater harvesting by basins (half-moon and circular), bunding and trenching can increase soil water content by reducing surface runoff and encouraging infiltration in different fruit crops. *Cenchrus ciliaris* and *Dicanthium annulatum* grasses are effective crops for interspace managements as they offered year-round ground cover and appeared to have the most desirable quality as a grass barrier for preventing soil erosion and surface runoff. Because these grasses had a vast and deep root system and also had the ability to maintain a precipitation-responsive nature. The characteristic of the *Cenchrus ciliaris* grass best suited for use in degraded lands is its apomictic nature (ability to generate clones from seeds). *Cenchrus ciliaris* grass can spread throughout the landscape in monotype stands, tiny clumps, and clusters due to its apomictic, invasive, and spreading characteristics. The clumpy nature of *Cenchrus ciliaris* grass and its strong, wide and deep root system suggest that it has erosion-controlling properties. The root system of a single club has the ability to cling to a soil system that is up to 1.0 m deep and between 1.5 and 2.0 m wide. Apart from this these grasses had higher economic and nutritional values and preferred grasses for quality feed for animals (Meena *et al*., 2023). *Cenchrus ciliaris* can rapidly invade native vegetation, weeds and other flora and fauna (Marshall *et.al.,* 2012).

However, the information in this aspect is lacking for the production potential of bael with inter space managements in degraded ecosystem of ravine lands. Hence, an experiment was laid out to evaluate the interspace management on the performance of bael (*Aegle marmelos*) in degraded lands of Chambal ravine.

2. MATERIALS AND METHODS

Experimental Site

The present study was carried out at Research Farm, ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Kota during 2007-2015 to evaluate the efficacy of interspace management systems for cultivation of bael under rainfed degraded lands of Chambal ravines. The experimental location is situated at a height of 256.9 m above mean sea level at 25º11'N latitudes and 75º51'E longitudes (Fig. 1). The experimental location is covered under semi-arid (dry, sub-humid) climatic conditions that particular location receives an average 753.9 mm of annual rainfall between mid-June to Sept from mid-Oct to mid-June, the climate remains dry. Table 1 contains the meteorological data of the experimental location. The soil texture of the experimental location ranges from clay loam to sandy clay loam and lightly alkaline with a low level of organic carbon and readily available N and P, while the quantity of readily available K was sufficient. Electrical conductivity (EC) is less than the critical limit *i.e.,* 4 dSm^{-1}. Low precipitation, high wind speeds, temperature extremes, poor soil fertility etc. are the main production system limitations in arid and semi-arid regions. Although bael is resilient to a variety of biotic and abiotic stresses, it still requires good nutrition and moisture management to produce quality production in degraded ravine areas.

Planting and Treatment Methodology

The study area has good soil depth and sub-soil has a calcareous layer and a hard pan. Hence pits of 1 m × 1 m × 1 m size were made at 8 m × 8 m spacing to ensure the proper development of the plant root system. The vegetatively propagated seedlings of bael *cv.* 'NB-5' was raised in the pit with the onset of monsoon in July 2007. The experiment was set up using randomised block design with four treatments (interspaces managements) *viz.,* clean tilled, clean tilled with halfmoon, halfmoon with *Cenchrus ciliaris* and halfmoon with *Dicanthium annulatum* with three replications. On the hump top of the ravine, the treatments were executed. During the months of April and May, pits are dug at a predetermined spacing. In May and June, the soil from the dugouts is let to dry off. All pebbles, dried roots, and other debris from the piled soils were removed. In each pit,

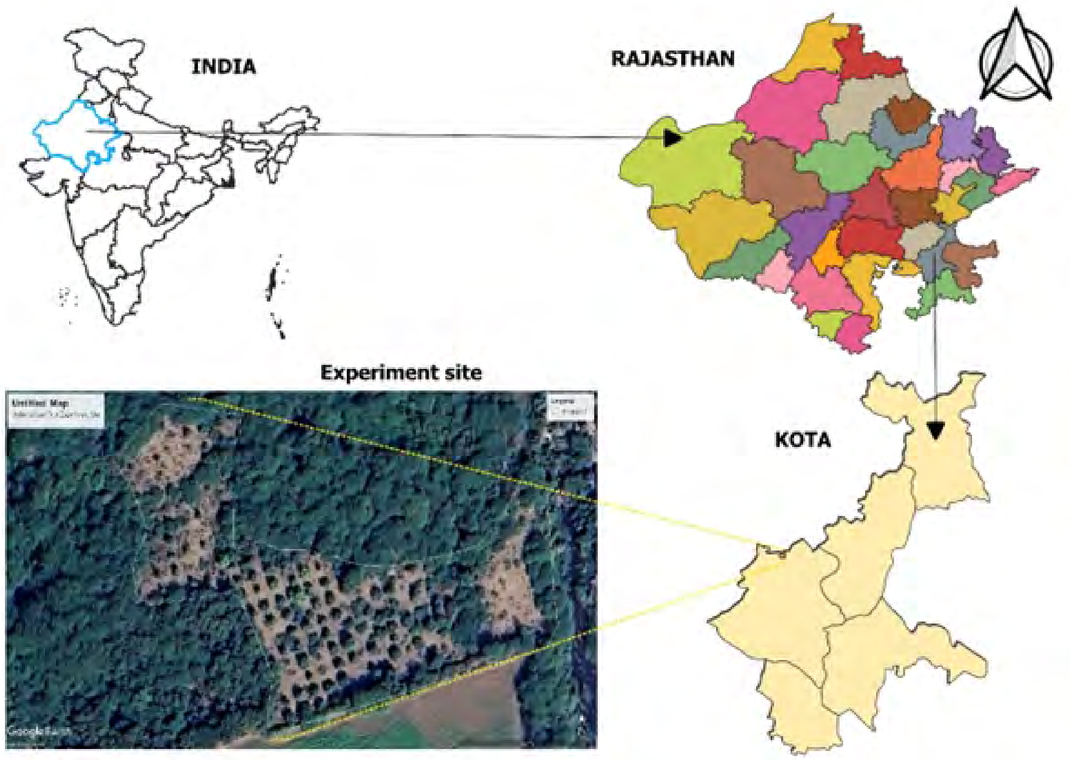

Fig. 1. Location map of study area in Chambal ravine of Kota district

Table: 1
Meteorological data of experimental site during the study period (2007-2015)

Month	Average of weather parameters (2007-2015)				
	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
January	19.5	5.7	78.4	34.7	6.9
February	23.2	8.5	76.7	30.3	6.7
March	29.3	13.1	61.0	17.1	15.2
April	34.3	18.8	42.7	11.9	3.9
May	37.4	23.8	36.5	13.3	8.0
June	39.6	27.9	60.2	31.6	116.9
July	33.7	26.2	83.0	59.4	267.6
August	31.7	25.1	88.2	64.6	224.5
September	33.2	23.7	85.8	53.3	82.6
October	34.4	17.8	82.2	29.3	5.8
November	29.8	12.5	89.9	31.5	14.8
December	24.8	8.0	90.1	40.9	1.0

combination of piled soil along with 25-30 kg of farm yard manure (FYM) and 100 g of pesticide powder was filled. One kg of single super phosphate (SSP) in the piles soil to maintain the availability of phosphorus. The pits were filled with a soil, SSP and FYM mixture. After the start of the first monsoon rains, already purchased one-year-old seedlings of variety (NB-5) was planted. The polythene wrappings of purchased or raised seedlings were removed and the seedlings are then placed in the prepared pit by drilling a small hole in the centre of the pit and then compressed slightly so that the seedlings are in close contact with the mixed soil for better establishment. A micro catchment of half-moon shape was prepared with gentle slope on the land of upstream of the planted seedlings resulted in receive the rainwater to the roots of plated seedlings besides creating a crescent-shaped bund on the downstream side of the pit at a distance of 1-1.5 m from the stem of the tree.

By digging a 15 cm deep hole or furrow over the general land slope, the interspaces are planted with the grasses *Cenchrus ciliaris* (Dhaman) and *Dicanthium annulatum* (Karad) at a spacing of 30 cm × 30 cm. Although these species are hardly affected by insects, a 0.2% solution of Chlorpyriphos (20 EC) helps to prevent termite infestation.

Plant Growth, Yield and Quality Estimation

Initial growth parameters (plant height, canopy diameter, canopy volume, leaf area and collar diameter) were recorded for four consecutive years from 2012 to 2015. A measuring pole was used to determine the height of plant from the ground to its top. Collar diameter was noted at 5 cm above the graft union by means of digital vernier calliper. With the aid of a measuring tape, the plant canopy spread was measured in east-west and north-south directions and a mean value was determined. Canopy volume was calculated the method described by the Obreza (1991) and expressed in (cubic metre). Leaf area was estimated by non-destructive millimetre graph paper method suggested by Pandey and Singh (2011).

Five fruits of uniform physiological age from each treatment plots were randomly selected on the date of observation from the harvested fruits of the tree. The fruits were thoroughly washed and weighed. Fruits were plucked at full maturity and observations were recorded on fruit yield of the plant (total number of fruits per plant, fruit yield per plant and fruit yield t ha^{-1}) and quality parameters (fruit weight, pulp weight, seed weight, number of seeds, weight of shell, weight per seed, weight of fibre, pulp: seed ratio, length of fruit, width of fruit, total soluble solids (TSS), total sugars, reducing sugars, acidity, ascorbic acid, TSS: acid ratio, sugar: acid ratio). Total numbers of fruits per plant were recorded from the first to last harvesting for various treatments. With the aid of a single pan balance, the weight of periodically collected mature fruits was measured from each treatment separately. The total yield (kg $plant^{-1}$) was determined. The fruit yield per hectare was computed by multiplying the fruit yield per plant by the number of plants per hectare, *i.e.,* 156 with 8 × 8 m spacing. Total plant yield was expressed in tonnes per hectare.

At the time of harvest, with the aid of vernier callipers, the length of the fruit from each treatment was measured longitudinally in centimetres. With the use of vernier callipers, the equatorial fruit diameter for each treatment was measured in centimetres and the average was computed. Fruit weight, pulp weight, seed weight, weight of fibre and weight of fruit shell were recorded with the help of electronic digital balance and expressed in gram.

Using a hand refractometer, the TSS of the fruit pulp were calculated at room temperature. The refractometer was calibrated with distilled water after every use and the values of the TSS was expressed in ^{0}B. Ascorbic acid and titrable acidity were measured using the method recommended by the AOAC (2000). Sugars were estimated by using the method of Hulme and Narain (1931). TSS: acid ratio was calculated by dividing the average value of TSS with the average value of titratable acidity. Juice was extracted manually and its percent was estimated on the weight basis with respect to the fruit weight. The pulp was calculated by deducting the weight of seed, peel and fibre from the total weight of the fruit. The data generated during course of study on various parameters were tabulated and statistically analysed as prescribed by Panse and Sukhatme (1978). The economic analysis of each tree species, in relation to various moisture conservation techniques, was conducted by applying the discounting principle of investment analysis. The B:C Ratio was calculated by considering a project duration of 20 yrs and applying a discount rate of 10%.

3. RESULTS AND DISCUSSION

Data were collected for four consecutive years of experimentation and then statistical analysis was performed. To summarise the results pooled analysis was done. The impact of various interspace managements on plant growth is reported in Table 2. The maximum plant height (4.91 m) was documented under clean tilled with halfmoon treatment (T_2) followed by halfmoon with *Cenchrus ciliaris* (4.67 m), halfmoon with *Dicanthium annulatum* (4.43 m) and minimum was recorded in clean tilled (4.05 m), respectively (Table 2). Tree growth was significantly affected by interspace management treatments. The highest plant spread in E-W and N-S directions (5.41 m and 5.26 m) were recorded in T_2 - (clean tilled with halfmoon) followed by 5.17 m and 5.12 m in T_3 - (halfmoon with *Cenchrus ciliaris*). The plant spread increased in almost all treatments over control (T_1- Clean tilled). Treatments T_2 and T_3 found statistically at par (Table 2). The maximum improvement in canopy volume (62.17 m^3) was recorded under clean tilled with halfmoon (T_2) treatment. Whereas, the minimum (42.54 m^3) was recorded in T_1 - (Clean tilled). Maximum collar diameter was also recorded in T_2 - clean tilled with halfmoon (19.46 cm) followed by T_3 - halfmoon with *Cenchrus ciliaris* (18.64 cm). The collar diameter varied significantly amongst the various treatments and ranged from 17.12 to 19.46 cm. The interspace management treatments showed statistically non-significant effect on leaf area. The highest average leaf area (91.69 cm^2) was recorded under clean tilled with halfmoon treatment whereas minimum was recorded in clean tilled (74.97 cm^2).

Table: 2
Effect of interspace managements on growth parameters of bael

Treatments	Plant height (m)	Plant spread (m)		Canopy volume (m^3)	Collar diameter (cm)	Leaf area (cm^2)
		E-W	N-S			
T_1 - Clean tilled (CT)	4.05	4.32	4.34	42.54	17.12	74.97
T_2 - CT + halfmoon (HM)	4.91	5.41	5.26	62.17	19.46	91.69
T_3 - HM + *Cenchrus ciliaris*	4.67	5.17	5.12	57.44	18.64	82.01
T_4 - HM + *Diacanthium annulatum*	4.43	4.78	4.63	55.92	18.27	78.70
CD (p = 0.05)	0.10	0.25	0.15	0.48	0.11	9.79

Differences in leaf area were found statistically at par among the treatments T_1, T_3 and T_4. The findings of current investigation are in confirmation with the findings in bael by Shukla *et al*. (2014).

The results in Table 3 show that regardless of treatments, the fruit yield was significantly higher in terms of number of fruits per plant, yield (kg plant^{-1}) and yield (t ha^{-1}). These yield variations were mainly attributed to the availability of conserved *in-situ* soil moisture in plant root zone for longer period of time. The highest number of fruits plant^{-1} of 25.97 was attained under treatment, T_2 (clean tilled with halfmoon) followed by 23.67 in T_3 (halfmoon with *Cenchrus ciliaris*) and 23.26 in T_4 (halfmoon with *Dicanthium annulatum*). The least number of fruits plant^{-1} (19.82) were found in T_1 (clean tilled), although the differences in variation in number of fruits per plant were found on par between T_3 and T_4 treatments. These results were comparable those obtained by Kumar *et al.* (2018) in Aonla.

Regarding fruit yield, there were significant differences among different treatments (kg plant^{-1}) and it ranges from 23.61 to 39.14 kg plant^{-1}. The highest fruit yield of 39.14 kg plant^{-1} was recorded in T_2 (clean tilled with halfmoon) followed by 32.66 kg plant^{-1} in T_3 (halfmoon with *Cenchrus ciliaris*) and 31.42 kg plant^{-1} in T_4 (halfmoon with *Dicanthium annulatum*). The fruit yield plant^{-1} was also converted on per hectare basis and exhibited a similar trend as fruit yield plant^{-1}. The highest fruit yield of 6.10 t ha^{-1} was recorded in T_2 (clean tilled with halfmoon) followed by 5.09 t ha^{-1} in T_3 (halfmoon with *Cenchrus ciliaris*) and 4.90 t ha^{-1} in T_4 (halfmoon with *Dicanthium annulatum*). The results also showed that the two treatments *viz.,* (T_2 and T_3) could produce an average of 1.91 t ha^{-1} additional fruit yield every year in comparison to the control (T_1). The minimum fruit yield t ha^{-1} (3.68) was obtained in T_1 - clean tilled treatment. More number of fruits might have increased the fruit yield per tree and productivity in bael with the treatment clean tilled with halfmoon shape micro-catchment interspace management for higher moisture conservation potential. The present findings are in close confirmatory with the results reported by Kumar and Shukla (2010). Better growth and yield in clean tilled with halfmoon (T_2) possibly as a result of higher *in-situ* water harvesting and the extended period of soil water availability to the plant. (Table's 2 and 3). These results support and consistent with findings of Shukla *et al.* (2014); Polara *et al*. (2013); Singh *et al.* (2011) and Samant *et al.* (2016) have stated the similar positive effects of *in-situ* rain water harvesting techniques on growth of the plants and fruit yield in bael, custard apple, ber and mango, respectively.

Data on quality attributing traits of bael fruit was shown in Tables 4 and 5 and it was noted that interspace management treatments significantly influenced the physico-chemical properties of bael fruit by reducing surface runoff, encouraging water infiltration rate and maintained sufficient available soil moisture around the root zone of plant for longer period of time. The weight of fruit was significantly higher (1507.32 g) in treatment T_2 (clean tilled with halfmoon) followed by 1380.03 g in T_3 (halfmoon with *Cenchrus ciliaris*) and 1351.21 g in T_4 (halfmoon with *Dicanthium annulatum*). The minimum weight of fruit (1191.71 g) was obtained in T_1 (clean tilled), though the differences in weight of fruit were found at par between T_3 (1380.03 g) and T_4 (1351.21 g) treatments (Table 4). Maximum pulp weight fruit^{-1} (1176.07 g) was also recorded in clean tilled with halfmoon (T_2) while minimum (811.78 g) was observed in T_1 (clean tilled). A significant response was observed among all the treatments with respect to pulp weight per fruit. Non-significant difference was recorded in seed weight per fruit among the treatments. The minimum seed weight per fruit (11.12 g) was observed in T_2 (clean tilled with halfmoon) followed by 11.19 g in T_3 (halfmoon with *Cenchrus ciliaris*) while maximum (11.31 g) seed weight per fruit was found in treatment T_1 (clean tilled). Number of seeds per fruit were recorded significantly lower (61.44) in treatment T_2 (clean tilled with halfmoon) followed by 63.27 in T_3 (halfmoon with *Cenchrus ciliaris*) and 63.74 in T_4 (halfmoon with *Dicanthium annulatum*). The maximum number of seeds per fruit (65.16) was obtained in T_1 (clean tilled). Weight of shell fruit^{-1}was observed significantly lower (283.81 g) under treatment T_4 (halfmoon with *Dicanthium annulatum*) followed by 291.67 g in T_3 (halfmoon with *Cenchrus ciliaris*) and 294.14 g in treatment T_2 (clean tilled with halfmoon). The highest

Table: 3
Effect of interspace managements on yield attributes of bael

Treatments	Number of fruits plant^{-1}	Fruit yield kg plant^{-1}	Fruit yield t ha^{-1}
T_1 - Clean tilled (CT)	19.82	23.61	3.68
T_2 - CT + halfmoon (HM)	25.97	39.14	6.10
T_3 - HM + *Cenchrus ciliaris*	23.67	32.66	5.09
T_4 - HM + *Diacanthium annulatum*	23.26	31.42	4.90
CD (p = 0.05)	0.37	1.16	0.18

Table: 4
Effect of interspace managements on physical parameters of bael fruits

Treatments	Weight of fruit (g)	Pulp weight fruit^{-1} (g)	Seed weight fruit^{-1} (g)	Number of seeds fruit^{-1}	Weight of fruit shell (g)	Weight seed (g)	Weight of fiber fruit^{-1} (g)	Pulp / seed ratio	Length of fruit (cm)	Width of fruit (cm)
T_1 - Clean tilled (CT)	1191.71	811.78	11.31	65.16	301.00	0.21	34.32	71.77	16.99	14.92
T_2 - CT + halfmoon (HM)	1507.32	1176.07	11.12	61.44	294.14	0.18	30.26	105.81	18.44	16.62
T_3 - HM + *Cenchrus ciliaris*	1380.03	992.63	11.19	63.27	291.67	0.20	32.54	88.62	17.94	15.98
T_4 - HM + *Diacanthium annulatum*	1351.21	938.43	11.20	63.74	283.81	0.20	33.02	83.84	17.67	15.93
CD (p = 0.05)	63.63	38.59	0.14	0.23	4.63	0.01	1.01	4.12	0.22	0.35

Table: 5
Effect of interspace managements on chemical parameters of bael fruits

Treatments	TSS (^{0}B)	Total sugars (%)	Reducing sugars (%)	Acidity (%)	Ascorbic acid (mg/100 g)	TSS: Acid ratio	Sugar: Acid ratio	B:C ratio
T_1 - Clean tilled (CT)	39.11	28.45	12.80	0.34	12.34	116.17	84.53	1.81
T_2 - CT+ halfmoon (HM)	37.56	25.78	11.59	0.36	15.12	105.33	72.29	2.19
T_3 - HM + *Cenchrus ciliaris*	38.46	26.61	11.97	0.34	14.52	113.12	78.25	2.10
T_4 - HM + *Diacanthium annulatum*	38.80	27.63	12.42	0.35	13.96	110.85	78.93	1.93
CD (p = 0.05)	0.47	0.73	0.33	0.0066	0.31	1.85	2.37	0.21

weight of shell fruit^{-1} (301.00 g) was obtained in T_1 (clean tilled), though the differences in weight of shell fruit^{-1} was found statistically at par between T_2 (294.14 g) and T_3 (291.67 g) treatments (Table 4). Seed weight was noticed significantly lower (0.18 g) in clean tilled with halfmoon (T_2) treatment while maximum (0.21 g) was recorded in T_1 (clean tilled). Same seed weight (0.20 g) was obtained under treatment T_3 and T_4. Weight of fibre fruit^{-1} was observed significantly lower (30.26 g) in treatment T_2 (clean tilled with halfmoon) followed by 32.54 g in T_3 (halfmoon with *Cenchrus ciliaris*) and 33.02 g in treatment T_4 (halfmoon with *Dicanthium annulatum*). Differences in weight of fibre per fruit was found statistically at par between T_3 (32.54 g) and T_4 (33.02 g) treatments. Significantly higher pulp-seed ratio (105.81) was obtained under treatment T_2 (clean tilled with halfmoon) followed by 88.62 in T_3 (halfmoon with *Cenchrus ciliaris*) and 83.84 in T_4 (halfmoon with *Dicanthium annulatum*) whereas, minimum pulp-seed ratio (71.77) was recorded in clean tilled (T_1) treatment. The maximum fruit length (18.44 cm) was recorded in clean tilled with halfmoon (T_2) treatment while minimum (16.99 cm) was observed in T_1 (clean tilled). Statistically significant differences were observed among all the treatments. Fruit width was found to be significantly higher (16.62 cm) in treatment T_2 (clean tilled with halfmoon) followed by 15.98 cm in T_3 (halfmoon with *Cenchrus ciliaris*) and 15.93 cm in T_4 (halfmoon with *Dicanthium annulatum*) and minimum (14.92 cm) was recorded in clean tilled (T_1) treatment. Differences in fruit width was found statistically at par between T_3 (15.98 cm) and T_4 (15.93 cm) treatments (Table 4). The aforementioned findings were confirmed the earlier findings of Shukla *et al.* (2014) and Samant *et al.* (2015 and 2016).

The results pertaining to variation in chemical properties such as TSS, total sugars, reducing sugars, acidity, ascorbic acid, TSS: acid ratio and sugar: acid ratio in respect of different interspace managements are presented in Table 5. Chemical properties with reference to different parameters varied significantly in all the treatments. There were significant differences between various treatments regarding TSS and it varied from 39.11°B to 37.56°B. Significantly higher TSS (39.11°B) was recorded in clean tilled (T_1) followed by 38.80°B in T_4 (halfmoon with *Dicanthium annulatum*) and 38.46°B in T_3 (halfmoon with *Cenchrus ciliaris*) treatment. Higher availability of TSS in fruit is due to less soil moisture availability in root zone of the plants resulting higher concentration of fruit pulp. Whereas minimum TSS (37.56°B) were observed under treatment T_2 (clean tilled with halfmoon). Higher value of TSS in the fruit have positive acceptance regarding medicinal and processing industry. Total sugars were recorded significantly higher (28.45%) under clean tilled (T_1) however, lowest total sugars (25.78%) were observed in clean tilled with halfmoon (T_2) treatment. Total sugars ranged from 28.45% to 25.78% in different interspace management treatments. Maximum reducing sugars (12.80%) were recorded in treatment T_1 (clean tilled) followed by 12.42% in T_4 (halfmoon with *Dicanthium annulatum*) and 11.97% in T_3 (halfmoon with *Cenchrus ciliaris*) treatment. Whereas minimum reducing sugars (11.59%) were observed under treatment T_2 (clean tilled with halfmoon). Significant differences reducing sugars were observed among all the treatments. Significant differences were not recorded among the values of acidity in different interspace management treatments. Differences in acidity was found to be on par with T_1 (0.34%) and T_3 (0.34%) treatments. There was significant difference in ascorbic acid content among all the treatments. Ascorbic acid was found to be significantly higher (15.12 mg / 100 g) in treatment T_2 (clean tilled with halfmoon) followed by 14.52 mg / 100 g in T_3 (halfmoon with *Cenchrus ciliaris*) and 13.96 mg / 100 g in T_4 (halfmoon with *Dicanthium annulatum*). The lowest ascorbic acid content (12.34 mg / 100 g) was obtained in T_1 (clean tilled) treatment. Maximum TSS: acid ratio (116.17) was found clean tilled (T_1) followed by 113.12 in T_3 (halfmoon with *Cenchrus ciliaris*) and 110.85 in T_4 (halfmoon with *Dicanthium annulatum*) whereas minimum (105.33) TSS-acid ratio was recorded under treatment T_2 (clean tilled with halfmoon). Significant variations were observed among all the treatments regarding TSS: acid ratio which ranged from 116.17 to 105.33. The maximum value of sugar: acid ratio (84.53) was observed in clean tilled (T_1) treatment and minimum (72.29) was in T_2 (clean tilled with halfmoon). However, treatment T_3 (78.25) and T_4 (78.93) was found statistically at par. Different interspace management practices had a considerable impact on forage production and the highest grass yield was documented in clean tilled with halfmoon (7.63 t DM ha^{-1}) with minimum in control (4.41 t DH ha^{-1}). Higher yield of grass was may be attributed to harvesting of more *in-situ* rainwater in halfmoon shape moisture conservation measure. Due to the nature of the grasses utilized in this study had substantial impact on fruit production and quality. Because they were supposed to involved in maintaining of good soil health and increase in soil moisture content by reduction of soil loss and runoff, soil aggregation, SOC content and they also provide the ground cover that leads to reduce the evaporation losses and increases the availability of water to the plants that directly leads to improve the plant growth and quality production of the fruits (Meena *et al*., 2023). Economics of various treatments were analysed on the basis of total cost of cultivation and net return and B:C ratio was calculated. Significantly higher B:C ratio (2.19) was recorded under treatment T_2 (clean tilled with halfmoon) followed by 2.10 in T_3 (halfmoon with *Cenchrus ciliaris*) and 1.93 in T_4 (halfmoon with *Dicanthium annulatum*). The minimum B:C ratio (1.81) was observed in treatment T_1 (clean tilled). Therefore, Bael (*Aegle marmelos)* is the highly suitable and remunerative fruit species for Chambal ravines planted in clean tilled with halfmoon micro catchment moisture conservation measure for long term basis. The findings of the current investigation are consistent with those reported by Shukla *et al*. (2014) in bael; Samant *et al.* (2015) in mango and Panigrahi *et al.* (2009) in Nagpur mandarin.

4. CONCLUSIONS

The present study indicated that different interspace management treatments utilized in this study had a noticeable impact on different parameters including growth, yield and quality. Among four different interspace management practices, clean tilled with halfmoon measure proved to be an efficient method. It also revealed that bael crop is highly suitable and also remunerative fruit crop for conservation horticulture in degraded ecosystem of Chambal ravines on long term basis.

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