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Yield, water productivity and economics of legume based agri-horti systems during establishment phase of pomegranate (*Punica granatum*) in hyper arid partially irrigated zone of western Rajasthan

M L SONI[1]*, BIRBAL[2], V NANGIA[3], A SAXENA[4], N D YADAVA[5], V SUBBULAKSHMI[6] and N S NATHAWAT[7]

ICAR-Central Arid Zone Research Institute, Regional Research Station, Bikaner, Rajasthan 334 004, India

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ABSTRACT

Field experiment was carried out at farmer's field in pre-bearing orchard of pomegranate (*Punica granatum* L.) during *rabi* and *kharif* season of 2015-16 and 2016-17, respectively in Bikaner district of Rajasthan to study the yield, water productivity and return of legume based intercropping during the establishment phase of pomegranate. There were five treatment combinations, i.e sole pomegranate, pomegranate + (fenugreek–clusterbean), pomegranate + (wheat-groundnut), sole fenugreek –clusterbean and sole wheat-groundnut. Pomegranate planted at 4m × 3m was maintained with drip and intercrops with mini-sprinkler irrigation system. Intercrops showed positive effect on height, girth and canopy spread of pomegranate over sole plantation. In agri-horti systems, the productivity of fenugreek, wheat, clusterbean and groundnut were higher by 20.5, 15.1, 16.4 and 14.9 %, respectively in grain and 18.0, 15.0, 31.6 and 12.4 %, respectively in straw/stover, as compared to sole cropping. The increase in productivity in agri-horti systems may compensate the area sacrificed by canopy coverage of trees up to some extent. Wheat-groundnut intercropped with pomegranate produced higher system productivity (5376 kg /ha) over fenugreek-clusterbean intercropped with pomegranate as well as sole fenugreek-clusterbean. Water productivity of sole orchard can be improved to 0.21 and 0.39 kg /m^3 in terms of economic yield (WP_{EY}), 0.64 and 0.99 kg/m^3 in terms of biological yield (WP_{BY}) and ₹ 108.8 and ₹ 151.1 /ha/mm, respectively in monitory terms by incorporating fenugreek–clusterbean and wheat-groundnut intercropping systems, respectively.

Key words: Agri-horti systems, Economics, Water productivity, Yield

About 31.7 million hectare (m ha) area of India (12% of country's total geographical area) has an arid climate, out of which 62 % area falls in Thar desert of western Rajasthan. This region is characterised by both physical and economic water scarcity. The greater proportion of agriculture in this region is resource constrained, subsistence and prasticed under rainfed conditions. Under these conditions, reports of yield losses associated with water stress and soil erosion are common (Soni *et al.* 2013; Santra *et al.* 2017).The arrival of water in the Thar Desert through Indira Gandhi Nahar Pariyojana (IGNP) has opened up land for irrigation and it became agriculturally productive zone. With the advancement of irrigation facility, growing of suitable horticultural crops are also becoming popular along with annual crops.

Pomegranate (*Punica granatum* L.) is gaining importance as an important fruit crop of arid and semi-arid region of India (Prasad 2000). The crop is grown commercially due to its high economic return, therapeutic and neutraceutical value (Sharma and Maity 2010) and its suitability for marginal lands without much care. The farmers grow the fruit crops as sole crop and the interspaces are left unused. Suitable crop combinations in the interspace of orchard during initial years can generate extra income, enhance productivity, ameliorate and improve ecological situation (Awasthi *et al*. 2008) in a sustainable manner.

In agri-horti systems, the selection of crop is most important. A careful selection of intercrop can reduce the mutual competition of resources to a considerable extent and may provide additional income to the farmers. Keeping in view the limitations of available water in the region, the

[1]Principal Scientist and corresponding author (soni_ml2002@yahoo.co.in); [2]Principal Scientist (birbalmeel@yahoo.com), [5]Principal Scientist and Head (narendra_yadava@yahoo.co.in); [6]Scientist (subbuforester@gmail.com); [7]Principal Scientist (nathawatns@rediffmail.com), ICAR- Central Arid Zone Research Institute, Regional Research Station, Bikaner, Rajasthan; [3]Senior hydrologist (V.Nangia@cgiar.org), Integrated Water and Management Programme, ICARDA, Jordan; [4]Principal Scientist (Anurag.Saxena@icar.gov.in), ICAR- Central Arid Zone Research Institute, Regional Research Station, Leh, Jammu &Kashmir;

crops with higher water productivity and more return may be included with these systems. Based on the above description, the exemplar crops grown with less irrigation water are clusterbean and fenugreek and with more irrigation water are groundnut and wheat. There is hardly any systematic research work on growing fruit trees with these crops in arid areas. Hence, the present experiment was conducted to study the performance of legume based intercrops in terms of yield, water productivity and returns during establishment phase of pomegranate orchard in hyper arid partially irrigated zone of western Rajasthan.

MATERIALS AND METHODS

Field experiment was carried out at farmer's field located at RD-33 of Charanwala branch of IGNP stage-II (72° 25' E longitude and 27° 51' N latitude) during *rabi* and *kharif* season of 2015-16 and 2016-17, respectively in Bikaner district of Rajasthan. The region falls in Agro-climatic zone I-C (Hyper arid partial irrigated zone) and is characterised by arid climatic conditions. The general topography of the area is undulating with various types of low to medium sand dunes. The region receives around 250 mm rainfall, 75% of which is received from the South-West monsoon during July–September. Rainfall conditions in the region are variable both in time and space. Potential evapotranspiration exceeds precipitation during most of the year. During the hottest period from May to June, mean daily maximum temperature rises up to 42.4°C.The soils of the experimental site was sand in texture with low soil organic carbon, alkaline in reaction and non-saline in nature. The bulk density (BD), cation exchange capacity (CEC), pH, permanent wilting point (PWP) and field capacity (FC) ranged between 1.52 to 1.57 Mg/m^3, 4.5 to 5.6 cmol (p$^+$)/kg, 7.9 to 8.3, 0.04 to 0.06 m^3/m^3 and 0.11 to 0.14 m^3/m^3, respectively. The CEC, pH, PWP, FC and soil water content increased with increase in soil depth, whereas BD, soil organic carbon, available N and EC decreased with increase in soil depth (Table 1).

The experiment was conducted in one and half year old pre-bearing orchard of pomegranate (Variety: Bhagwa) spaced at 4 m × 3 m apart. In the interspace of pomegranate, field crops were sown in a plot size of 3 m×12 m in randomized block design with five treatments and four replications. The intercrops were sown 0.5 m away from pomegranate tree in either side of the trunk. The treatment combinations are as follows: T_1: sole pomegranate, T_2: pomegranate + (fenugreek-cluster bean), T_3: pomegranate + (wheat -groundnut), T_4: sole fenugreek-cluster bean and T_5: sole wheat -groundnut. The recommended packages of practices were followed for pomegranate and intercrops. Pomegranate plants were maintained with drip irrigation during dry periods (4 l/tree/day for sole tree and 4 l/tree at every 3rd day for trees in intercropping system). Intercrops were irrigated with mini-sprinkler irrigation. The total amount of irrigation water applied in the system (irrigation + rainfall) has been shown in Fig 3. Plant protection measures and intercultural operations were done as and when required for both the components.

Physico-chemical properties of the soil were analyzed by following the standard procedures (Jackson 1973). The growth observations on pomegranate and intercrops were recorded during the experimentation period. System productivity was calculated in terms of grain clusterbean equivalent yields (CEY). The CEY for different intercrops (both *kharif* and *rabi* season crops including fruit crop) was calculated based on selling price of the produce and yield

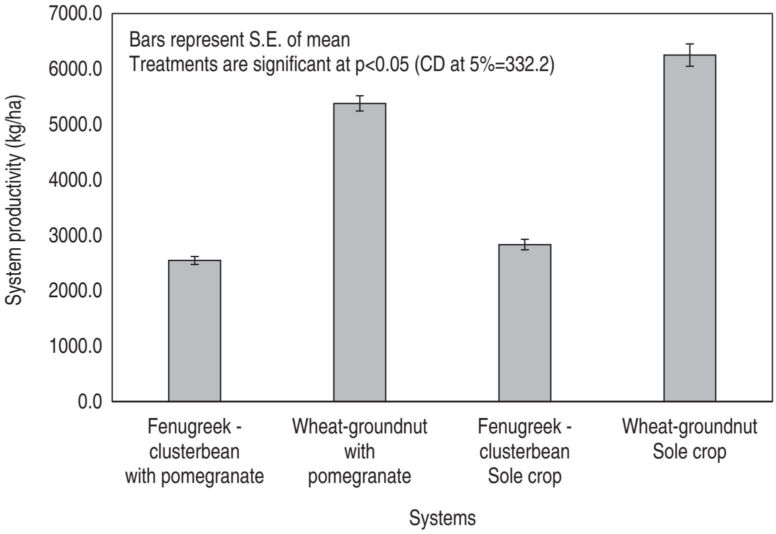

Fig 1 System productivity in terms of grain clusterbean equivalent yield (CEY) in pomegranate based agri-horti and sole cropping systems.

Table 1 Physical and chemical properties of soil at experimental site

Depth (m)	Sand (%)	Silt (%)	Clay (%)	SOC (%)	pH_2	EC (dS/m)	FC (m^3/m^3)	PWP (m^3/m^3)	CEC [c mol (p^+) /kg]	BD (Mg /m^3)	Available nutrients (kg/ha)		
											N	P	K
0-0.15	89.0	6.9	4.1	0.11	7.9	0.22	0.11	0.04	4.6	1.57	92	8.2	232
0.15-0.30	88.4	7.4	4.2	0.08	8.0	0.21	0.11	0.04	4.5	1.53	86	8.6	240
0.30-0.60	88.8	7.6	3.6	0.08	8.2	0.22	0.13	0.06	4.8	1.55	86	9.2	252
0.60-0.90	86.4	8.3	5.3	0.06	8.2	0.15	0.14	0.06	5.4	1.54	74	8.2	260
0.90-1.00	86.2	8.3	5.5	0.06	8.3	0.16	0.14	0.06	5.6	1.52	74	9.6	260

of intercrops using the formula shown in Eq 1. The CEY of individual intercrops of both seasons was summed up to obtain overall system productivity of individual treatments.

$$\text{CEY (kg/ha)} = \frac{\text{Yield of intercrops (kg/ha)} \times \text{Selling price (₹/kg)}}{\text{Selling price of clusterbean (₹/kg)}} \quad (1)$$

Water productivity (kg/m^3) was calculated as water quantity applied (rainfall + irrigation) in each treatment divided on the obtained yield (Eq 2).

$$\text{Water productivity (WP)} = \frac{\text{Yield (kg/ha)}}{\text{Water applied (m}^3\text{/ha)}} \quad (2)$$

The economics was calculated by considering the actual expenditure incurred on various operations, prevalent labour charges, prevailing market price of inputs and crop produce. The benefit: cost ratio was calculated dividing net returns by the cost of cultivation of individual treatment. The data recorded on various characteristics were subjected to Fisher's method of analysis of variance and interpretation of data was taken up as per Sukhatme and Amble (1995).

RESULTS AND DISCUSSION

Growth of pomegranate

Intercrops grown in association with pomegranate did not offer any competition on growth and development of pomegranate which may be due to different rooting behaviour of the pomegranate and intercrops. Intercrops showed positive effect on growth of pomegranate as it improved the height, girth and canopy spread over sole pomegranate system (Table 2). Average annual increase in height of pomegranate with wheat-groundnut and fenugreek-clusterbean cropping system was 41.0 and 38.5 %, respectively as compared to 21.3 % in sole pomegranate. Similarly, percent increase in girth and canopy spread of pomegranate was 72.3 and 23.6 % with wheat-groundnut and 60.5 and 18.7% with fenugreek-clusterbean cropping system as compared to 45.5 and 8.8 %, respectively in sole pomegranate. This might be due to the fact that adoption of intercropping systems in pomegranate helps in efficient utilization of natural resources as well as it improves the input use efficiency in the system than sole plantation where the interspaces were left uncultivated and did not receive any additional input in terms of fertilizer, supplemental irrigation, additional biomass etc. (Panda *et al*. 2003). Since the experimental soil was very low in soil organic carbon and N, even a minimal amount of additional source of N helped in better growth and development of plants. In the present study, clusterbean and groundnut as legume crops helped in nitrogen fixation and addition of nutrients through leaf litter fall and roots residues, which increased the growth of intercropped pomegranate as compared to sole trees. Similar effects of intercropping with leguminous crops (mothbean, greengram, blackgram, cowpea, clusterbean) on vegetative growth have been reported by other workers in aonla (Kumar and Pandey 2004; Awasthi *et al.* 2009), in citrus (Yadava *et al.* 2013; Yadava *et al.* 2017), in ber (Saroj *et al.* 2003; Yaragattikar and Itnal 2003; Birbal *et al*. 2013) and in guava (Shweta *et al*. 2015).

Table 2 Growth of pomegranate as affected by different intercrops in agri-horti systems (values are ± 1 standard error)

Treatment	Nov. 2015	Nov. 2016	Per cent increase
	Height (cm)		
Sole pomegranate	122±1.01	148±0.97	21.3
Pomegranate + wheat-groundnut	117±1.47	165±1.09	41.0
Pomegranate + fenugreek-clusterbean	122±1.00	169±0.95	38.5
	Girth (cm)		
Sole pomegranate	10.17±0.13	14.8±0.11	45.5
Pomegranate + wheat-groundnut	9.75±0.09	16.8±0.07	72.3
Pomegranate + fenugreek-clusterbean	10.15±0.16	16.3±0.13	60.5
	Average canopy spread (cm)		
Sole pomegranate	113.7±1.41	123.8±1.37	8.8
Pomegranate + wheat-groundnut	118.2±1.28	146.2±1.28	23.6
Pomegranate + fenugreek-clusterbean	122.3±1.45	145.2±1.03	18.7

Grain and straw yield of crops

Productivity of both *rabi* (wheat and fenugreek) and *kharif* (groundnut and clusterbean) crops in agri-horti system was significantly higher as compared to sole cropping (Table 2). In agri-horti systems, the productivity of fenugreek, wheat, clusterbean and groundnut were higher by 20.5, 15.1, 16.4 and 14.9 %, respectively in grain and 18.0, 15.0, 31.6 and 12.4 %, respectively in stover/straw, as compared to sole cropping. It may be ascribed to microclimate moderation created by pomegranate plants (Pateria *et al*. 2005), which acts as wind break to protect the crop against wind erosion and reduces the rate of transpiration (Soni *et al.* 2017). The increase in productivity due to microclimate moderation by the pomegranate trees in agri-horti systems may compensate the area lost by canopy coverage of trees upto some extent. In agri-horti systems, about 25% area was sacrificed in tree cover and only 75 % effective area was covered by intercrops. As a result of this, the overall yield of crops decreased on hectare basis in agri-hoti systems. The mean grain yield of crops viz. fenugreek (997 kg/ha), wheat (2481 kg/ha), clusterbean (759 kg/ha) and groundnut (2511 kg/ha)was significantly less in agri-horti system as compared to sole cropping (Table 3). The magnitude of reduction in grain yield in agri-horti system was 9.5 % in fenugreek, 13.6 % in wheat, 12.7 % in clusterbean and 13.8% in groundnut. Similarly, the straw yield was reduced to the tune of 12.3% in fenugreek, 13.7% in wheat, 1.3 %in clusterbean and 15.6% in groundnut.

Table 3 Grain and straw/stover yield (kg/ha) of different intercrops grown as sole and in agri-horti system

Treatment	Yield (kg/ha)			
	Rabi		*Kharif*	
	Grain yield	Straw/ stover yield	Grain yield	Stover yield
With pomegranate				
Fenugreek-clusterbean	997 (1328)	1212 (1616)	759 (1012)	2240 (2987)
Wheat-groundnut	2481 (3307)	3951 (5268)	2511 (3347)	3720 (4959)
Sole crop				
Fenugreek-clusterbean	1102	1382	870	2270
Wheat-groundnut	2872	4581	2912	4406
SEm.±	58.6 (68.9)	63.2 (70.6)	50.4 (57.3)	63.5 (75.0)
CD (P=0.05)	187.7 (220.3)	202.1 (225.8)	161.4 (183.4)	203.2 (239.9)

Figures in parenthesis represent system productivity

System productivity

The system productivity was calculated in terms of grain clusterbean equivalent yield (CEY). The maximum CEY (6248 kg/ ha) was observed in sole wheat-groundnut system (Fig 5). Wheat-groundnut intercropped with pomegranate produced higher system productivity (5376 kg/ ha) over sole fenugreek-clusterbean cropping system as well as fenugreek-clusterbean intercropped with pomegranate. Only 13.9 and 10.0% CEY was reduced in pomegranate +wheat-groundnut and pomegranate +fenugreek-clusterbean agri-horti systems over sole cropping of wheat-groundnut and fenugreek-clusterbean, respectively. This shows that during establishment phase of pomegranate orchard, agri-horti systems with wheat-groundnut or fenugreek- clusterbean can be a better option than sole tree system.

Water use and water productivity

The maximum amount of water was applied in wheat-groundnut intercropping system with pomegranate and minimum in sole pomegranate (Fig 2). Wheat- groundnut was found to be high water requiring cropping systems compared to fenugreek-clusterbean.Water productivity in terms of economic yield (WP_{EY}) and biological yield (WP_{BY}) in different systems ranged from 0.21-0.66 and 0.64-1.18 kg/ m^3, respectively (Fig 3). During establishment phase of orchards, water productivity of sole plantation remains zero because no economic yield was obtained, which can be improved to 0.21 and 0.39 kg/m^3 in terms of WP_{EY} and 0.64 and 0.99 kg /m^3 in terms of WP_{BY} by incorporating intercrops of fenugreek –clusterbean and wheat-groundnut systems, respectively. However, the water productivity of agri-horti systems during establishment phase was significantly less than sole cropping systems because the total amount of water consumed in agri-horti systems was higher than their respective sole cropping and the yield of intercrops was also lower due to the sacrifice of the area under tree cover. The loss of yield due to sacrifice of area under fruit trees have also been reported by Yaragattikar and Itnal (2003).

Water productivity in monetary terms of gross return varied from ₹ 108.8-174.9/ha/mm (Fig 4). Inter-cropping of pomegranate with fenugreek–clusterbean and wheat-groundnut can improve the water productivity in monetory terms to the tune of ₹ 108.8 and 151.1/ha/mm, respectively over sole plantation during establishment phase.

Economic returns

The cost of production and returns of the intercrops in association with pomegranate and sole crops are given in Table 4. Economic analysis of different cropping system showed that wheat – groundnut produced higher returns in both sole crops as well as agri-horti systems. The B:C ratio of sole crops were higher as compared to agri-horti system. This was due to the area sacrificed under plantation in agri-horti system. However, as compared with sole orchard, an additional income of ₹ 1.07 lakhs can be obtained with wheat-groundnut intercropped with pomegranate which was even higher than sole cropping of fenugreek-clusterbean.

It could be concluded that intercrops did not exert any competition neither on the growth and development of pomegranate nor the productivity of intercrops were affected by pomegranate. Rather, they promote the growth of pomegranate. Groundnut-wheat and clusterbean-fenugreek can profitably be cultivated with higher productivity in the inter space of pomegranate during establishment

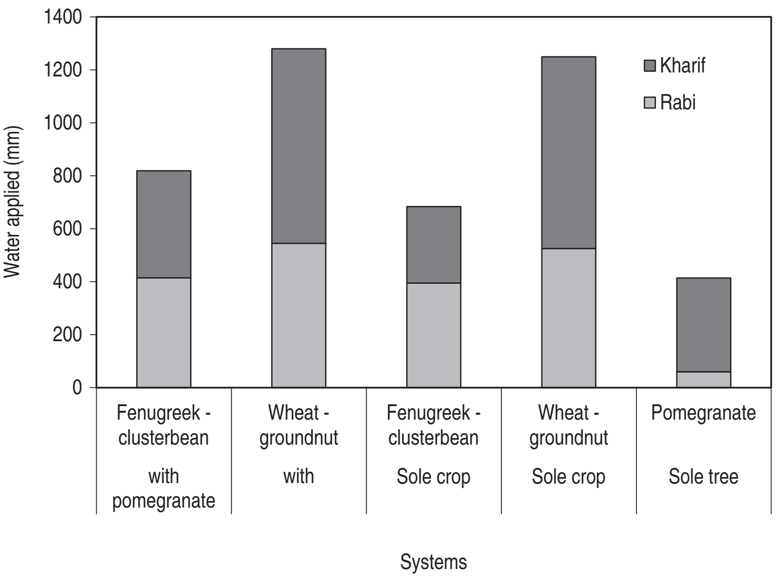

Fig 2 Water applied (irrigation+rainfall) in pomegranate based agri-horti and sole cropping systems.

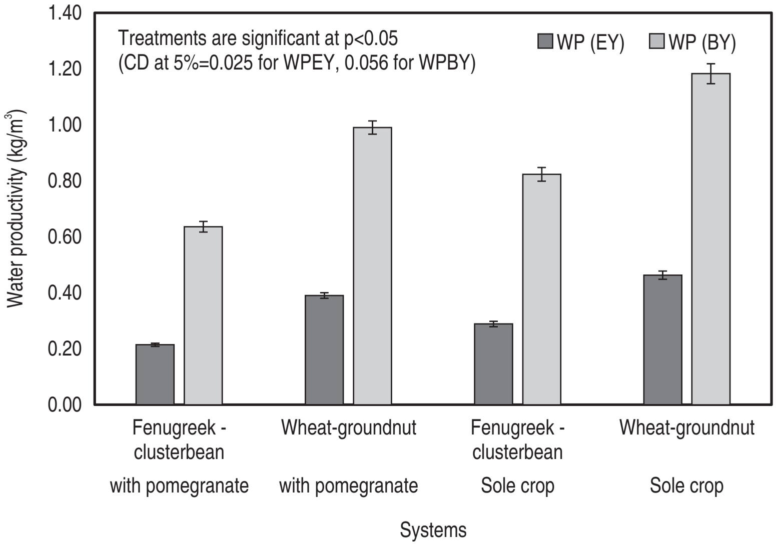

Fig 3 Water productivity (WP) in terms of crop yield (EY= economic yield and BY= biological yield) of pomegranate based agri-horti system and sole cropping systems.

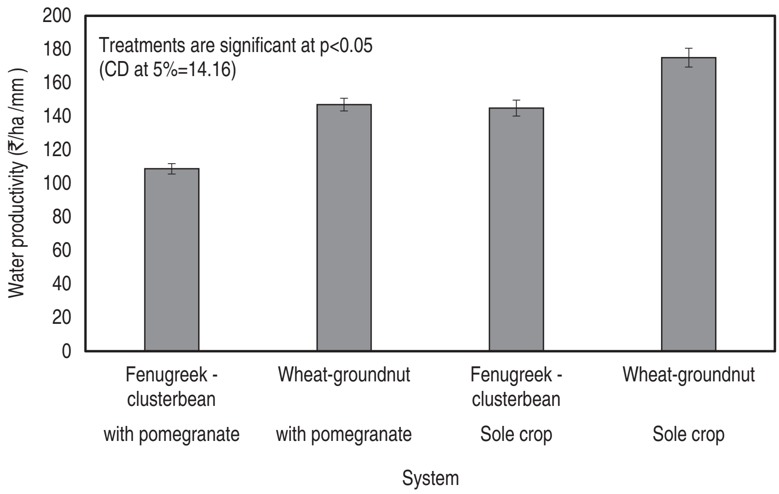

Fig 4 Water productivity in terms of gross return (WP_{GR}) of pomegranate based agri-horti systems and sole cropping systems.

Table 4 Economic performance of different intercrops grown as sole and in agri-horti system

Treatment	*Cost of production (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
With pomegranate				
Fenugreek-clusterbean	57955	89085.8	31130.8	0.54
Wheat-groundnut	80920	188165	107245	1.33
Sole crop				
Fenugreek-clusterbean	35475	98998	63523	1.79
Wheat-groundnut	58440	218711	160271	2.74
Sole Pomegranate	22480	--	--	---

* Cost of production includes the cost incurred in establishment of orchard also.

phase of orchard. Water productivity of sole orchard can be improved to 0.21 and 0.39 kg/ m^3 in terms of economic yield (WP_{EY}) and 0.64 and 0.99 kg/ m^3 in terms of biological yield (WP_{BY}) by incorporating fenugreek – clusterbean and wheat-groundnut intercropping systems, respectively.The farmers can get additional income during the gestation period of fruit trees till they come in fruiting. However, the system needs to be assessed for longer term sustainability, productivity, profitability and soil health improvement.

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REFERENCES

Awasthi O P, Saroj P L, Singh I S and More T A. 2008.Fruit-based cropping system for arid regions. Central Institute for Arid Horticulture. Technical Publication No.25, pp 1-18.

Awasthi O P, Singh I S and More T A. 2009. Performance of intercrops during establishment phase of aonla (*Emblica officinalis*) orchard. *Indian Journal of Agricultural Sciences* **79 (8)**: 587–91.

Birbal, Rathore V S, Nathawat N S, Bhardwaj S and Yadava N D. 2013. Influence of irrigation methods and mulches on pea (*Pisum sativum* L.) In ber (*Ziziphus mauritiana*) based vegetable Production system under tropical climate of Rajasthan. *Legume Research* **36(6)** : 557–562.

Jackson M L. 1973. *Soil Chemical Analysis*.Prentice Hall of India Pvt Ltd, New Delhi.

Kumar D and Pandey V. 2004. Vegetative growth of aonla as influenced by intercrops under rainfed conditions of Agra. *Orissa Journal of horticulture* **32**: 109–11.

Panda M M, Nandi A, Bhoi N, Senapati N, Barik K C, Sahu S K and Sahoo B C. 2003. Studies on identification of suitable intercrops for degraded land management in the North Central Plateau Agroclimatic Zone of Orissa. *Journal of Research* Orissa University of Agriculture and Technology **21(1)**: 62–66.

Pateria D K, Jaggi S, Batra P K and Gill A S. 2005. Modeling the impact of fruit trees on crop productivity. *Indian Journal of Agricultural Sciences* **75(4)**: 222–4.

Prasad R N. 2000. Varietal evaluation of pomegranate under arid conditions. *Annals of Arid Zone* **39(4)**: 427–430.

Santra P, Moharana P C, Mahesh Kumar , Soni M L, Pandey C B, Chaudhari S K and Sikka A K. 2017. Crop production and economic loss due to wind erosion in hot arid ecosystem of India. *Aeolian Research* **28:** 71–82.

Saroj P L, Dhandar D G, Sharma B D, Bhargava R and Purohit C K. 2003. Ber (*Ziziphus mauritiana* Lamk.) based agri-horti system: A sustainable land use for arid ecosystem. *Indian*

Journal of Agroforestry **5**: 30–35.

Sharma J and Maity A. 2010.Pomegranate phytochemicals: Neutraceutical and therapeutic value. (In) Chandra R (Ed.). *Pomegranate. Fruit, vegetable and cereal science and biotechnology* 4 (Special issue 2), pp 56-76.

Shweta, Baloda S, Bhatia S K and Sharma J R. 2015. Intercropping studies in guava orchards. *InternationalJournal of Tropical Agriculture* **33(3)**: 2189–2192.

Soni M L, Subbulakshmi V, Sheetal K R, Yadava N D and Dagar J C. 2017. Agroforestry for increasing farm productivity in water-stressed ecologies. (In) Dagar J C and Tewari V P (Eds). *Agroforestry- Anecdotal to Modern Science,* pp. 369-412. Springer Nature, Singapore Pte Ltd.

Soni M L, Yadava N D, Beniwal R K, Singh J P, Birbal, Sunil Kumar. 2013. Grass based strip cropping systems for controlling soil erosion and enhancing system productivity under drought situations of arid western Rajasthan. *International Journal of Agriculture and Statistical Sciences* 9(**2**): 685–692.

Sukhatme P V and Amble V N. 1995. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.

Yadava N D, Soni M L, Nathawat N S and Birbal. 2013. Productivity and growth indices of intercrops in agri-horti-silvi system in arid Rajasthan. *Annals of Arid Zone* **52(1)**: 61–65.

Yadava N D, Soni M L, Rathore V S and Renjith P S. 2017. Performance of fruit trees (drip irrigation) and intercrops (rainfed) under agri-hortti system in arid western Rajasthan. *Indian Journal of Arid Horticulture* **12 (1-2)**: 75–79.

Yaragattikar A T and Itnal C J. 2003. Studies on ber based intercropping systems in the northern dry zone of Karnataka. *Karnataka Journal of Agricultural Sciences* **16 (1)**: 22–25.