



Performance of Kinnow (*Citrus reticulata* Blanco) based Agri-horticultural Systems during Intermediate Stage of Fruiting in Light Textured Soil of Arid Rajasthan

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Abstract: Kinnow (*Citrus reticulata* Blanco) cultivation is increasing in IGNP area due to its profitability and good market value. It is cultivated as sole crop and the interspaces are left unutilized. Growing suitable intercrops in the left over spaces of kinnow may generate extra income to the farmers. Hence, an experiment was conducted to study the productivity and profitability of kinnow based intercropping systems in hyper arid partially irrigated zone of western Rajasthan. The study was conducted during rabi and kharif seasons of 2015-16 and 2016-17, respectively in seven years old plantations of kinnow with five treatments viz (i) kinnow + wheat - groundnut, (ii) kinnow + fenugreek - clusterbean, (iii) sole wheat - groundnut, (iv) sole fenugreek - clusterbean and (v) sole kinnow. Intercropping showed positive effect on growth and yield of kinnow with highest yield in kinnow + wheat - groundnut followed by kinnow + fenugreek - clusterbean. However, the yield of intercrops decreased by 37-42% when grown in association with kinnow as compared to their sole cropping. The annual system productivity in terms of clusterbean equivalent yield (CEY) was minimum in sole kinnow (1.15 t ha⁻¹) and increased when kinnow was intercropped with fenugreek-clusterbean (2.95 t ha⁻¹) and wheat-groundnut (4.97 t ha⁻¹). There were 2.56 and 4.33 times higher annual system productivity of kinnow + fenugreek-clusterbean and kinnow + wheat - groundnut intercropping system as compared to sole kinnow. The share of kinnow in system productivity was 42.0 and 24.4% and in net return was 43.5 and 18.0% in kinnow + fenugreek-clusterbean and kinnow + wheat - groundnut intercropping system, respectively. Intercropping systems of kinnow + fenugreek - clusterbean and kinnow + wheat - groundnut showed higher physical as well as economic water productivity as compared to sole kinnow. The water productivity in terms of gross return (WP_{GR}) increased from Rs. 4.99 m⁻³ in sole kinnow to Rs. 7.94 and 9.89 m⁻³ in kinnow + fenugreek - clusterbean and

kinnow + wheat -groundnut intercropping systems, respectively. Net return and BCR of intercropping systems were more as compared to sole kinnow which indicated that the intercropping systems of kinnow provides higher economic benefits through additional return from crop produce.

Key words: Agri-horti systems, economic returns, kinnow, water productivity, yield.

Arid region comprise around 31% of drylands at global and 18% at national level in India. The region is characterised by extremes of climatic conditions with low and erratic rainfall, high temperature and frequent drought. The soils of the region are deficient in nutrients and moisture with poor physical conditions (Kumar *et al.*, 2009). Yield reductions and economic losses associated with water stress and soil erosion are commonly observed (Soni *et al.*, 2013; Soni *et al.*, 2017; Santra *et al.*, 2017). The region once known for sandstorms and poor vegetation cover is now transforming from grey to green. This has become possible due to the establishment of irrigation facility through Indira Gandhi Nahar Pariyojana (IGNP). As the irrigation from IGNP advanced, growing suitable fruit crops viz. pomegranate, kinnow, karonda, acid lime *etc.* has also become possible in the region.

Among the fruit crops, kinnow (*Citrus reticulata* Blanco) cultivation is gaining importance in IGNP area due to its profitability and good market value. After Sriganganagar and Hanumangarh, its area is increasing in Bikaner too. Normally, the farmers grow kinnow as sole crop leaving the interspaces unutilized. Growing suitable intercrops in the left over spaces of kinnow can make the system more economic in terms of production and generating extra income. Keeping in view the limitations of water availability in the region, water efficient crops with more return and compatible throughout the growing season of main crop may be included as intercrops. Previous experiments conducted in different part of India have shown that the yield stability is greater with intercropping systems of sweet orange (Ghosh and Pal, 2010), ber (Birbal *et al.*, 2013), guava (Swain *et al.*, 2013), aonla (Awasthi *et al.*, 2008) and pomegranate (Soni *et al.*, 2020). However, there has been

limited scientific research on the kinnow-based intercropping system in the hot arid region of Rajasthan. Therefore, the present experiment was conducted to study the productivity and profitability of kinnow based intercropping systems compared to its sole cropping in hyper arid partially irrigated zone of western Rajasthan.

Materials and Methods

Location

The experiment was conducted at farmer's field located at RD-71 of Charanwala branch of IGNP stage-II (72°10'23.81''E longitude and 27°54'28.36''N latitude) 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 region receives approximately 250 mm rainfall, with 75% occurring from the South-West monsoon during July to September. Potential evapo-transpiration exceeds precipitation during most of the year. During the hottest period from May to June the mean daily maximum temperature rises up to 42.4°C while in the winter the average monthly temperature can drop below 5.5°C.

Soil characteristics

Physico-chemical properties of the soil were analysed by their standard procedures (Jackson, 1973). The soils of the area are mostly sand in texture but due to the deposition of silt and clay particles through continuous irrigation by canal water, the surface soil texture of experimental site modified to loamy sand. The soil pH was alkaline in reaction and increased with depths. The soil organic carbon was low throughout the soil profile and it decreased with soil depth (1.6 g kg⁻¹ in upper 15 cm soil depth to 0.6 g kg⁻¹ in lower 100 cm soil depth). The bulk density (BD), Cation exchange capacity (CEC), field capacity (FC) and permanent wilting point (PWP) ranged between 1.46 to 1.52 Mg m⁻³, 4.8-7.6 cmol (p⁺) kg⁻¹, 0.12 to 0.18 m³ m⁻³ and 0.05 to 0.07 m³ m⁻³ respectively. The CEC, FC and PWP increased with increase in soil depth whereas, bulk density decreased with increase in soil depth. Soil available nitrogen and phosphorus decreased with soil depth and were in low and medium category, respectively. Available potassium was more in upper profiles and decreased with soil depth (Table 1).

Table 1. Physical and chemical properties of experimental soil

Depth (m)	Sand (%)	Silt (%)	Clay (%)	SOC (%)	pH ₂	EC (dS m ⁻¹)	FC (m ³ m ⁻³)	PWP (m ³ m ⁻³)	CEC [c mol (P ⁺) kg ⁻¹]	BD (Mg m ⁻³)	Available nutrients (kg ha ⁻¹)		
											N	P	K
0-0.15	78.0	13.0	9.0	0.16	7.7	0.18	0.18	0.07	7.6	1.46	112	12.2	248
0.15-0.30	82.4	9.4	8.2	0.14	8.0	0.20	0.14	0.06	5.5	1.48	96	9.6	252
0.30-0.60	86.8	7.6	5.6	0.10	8.1	0.22	0.13	0.06	4.8	1.54	86	9.2	252
0.60-0.90	86.4	7.3	6.3	0.06	8.2	0.15	0.13	0.06	4.9	1.54	84	8.2	232
0.90-1.00	86.2	8.3	5.5	0.06	8.2	0.16	0.12	0.05	5.2	1.52	74	9.6	212

Experimental detail and data analysis

Field experiments were carried out during rabi and kharif seasons of 2015-16 and 2016-17, respectively in seven years old plantations of kinnow planted at 8 m × 6 m apart. In the interspaces of kinnow, the crops were sown in a plot size of 6 m × 12 m with five treatments and four replications. The intercrops were sown 1.0 m away from kinnow tree in either side of the trunk. The treatment combinations were as follows: T₁: kinnow + wheat -groundnut, T₂: kinnow + fenugreek-clusterbean, T₃: sole wheat - groundnut, T₄: sole fenugreek-clusterbean and T₅: sole kinnow. The recommended packages of practices were followed for kinnow and intercrops.

Kinnow plants were irrigated by making basins around the plants and intercrops were irrigated with mini sprinkler irrigation system. The total amount of irrigation water applied in the system (irrigation + rainfall) has been shown in Fig 1. Plant protection measures and intercultural operations were done as and when required for fruit trees and crops.

The growth and yield of kinnow and intercrops were recorded. The fruit crop (kinnow) was in intermediate stage of production and the major crop of the area is clusterbean which the farmers are growing. Hence we have calculated clusterbean equivalent yield (CEY). The CEY of individual components (intercrops of both seasons and fruit yield) was calculated on the basis of selling price of the each produce (Eq. 1) and summed up to obtain overall system productivity of individual treatments.

$$\text{CEY (kg ha}^{-1}\text{)} = \frac{\text{Yield of intercrops (kg ha}^{-1}\text{)} \times \text{Selling price (Rs. kg}^{-1}\text{)}}{\text{Selling price of Clusterbean (Rs. kg}^{-1}\text{)}} \quad \dots(1)$$

Water productivity (kg m⁻³) in terms of water expense was calculated as the total amount of

water applied (rainfall + irrigation) in each treatment divided on the total yield (Eq.2).

$$\text{Water productivity} = \frac{\text{Yield (kg ha}^{-1}\text{)}}{\text{Water applied (m}^3\text{ ha}^{-1}\text{)}} \dots(2)$$

The economic analysis was carried out by considering the actual expenditure incurred on various agricultural operations, cost of inputs and labor charges, and prevailing market price of crop produce. Total gross income was calculated by totaling the income from selling price of economic produce of the season viz. grains, straw and kinnow fruits (Eq. 3). Net income was calculated as the difference between total gross income and total cost of cultivation. The benefit: cost ratio (BCR) was calculated dividing gross returns by the cost of cultivation of individual treatment (Eq. 4).

$$\text{Gross income (Rs. ha}^{-1}\text{)} = [\text{Grain yield (kg ha}^{-1}\text{)} \times \text{MSP of grain (Rs. kg}^{-1}\text{)}] + [\text{Straw yield (kg ha}^{-1}\text{)} \times \text{market price of straw (Rs. kg}^{-1}\text{)}] + [\text{Fruit yield of kinnow (kg ha}^{-1}\text{)} \times \text{market price of kinnow fruit (Rs. kg}^{-1}\text{)}] \quad \dots(3)$$

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income (Rs.)}}{\text{Total cost (Rs.)}} \quad \dots(4)$$

To test whether the differences between treatment means were statistically significant or not, the data recorded on various attributes were statistically analysed in randomised block design (Sukhatme and Amble, 1995).

Results and Discussion

Growth of kinnow

Intercropping showed positive effect on various growth attributes of kinnow viz. plant height, girth and canopy spread over sole plantations (Table 2). Average annual increment in plant height of kinnow with wheat-groundnut and fenugreek-clusterbean intercropping system was more (11.5 and 8.5%, respectively) as compared to sole kinnow (7.3%).

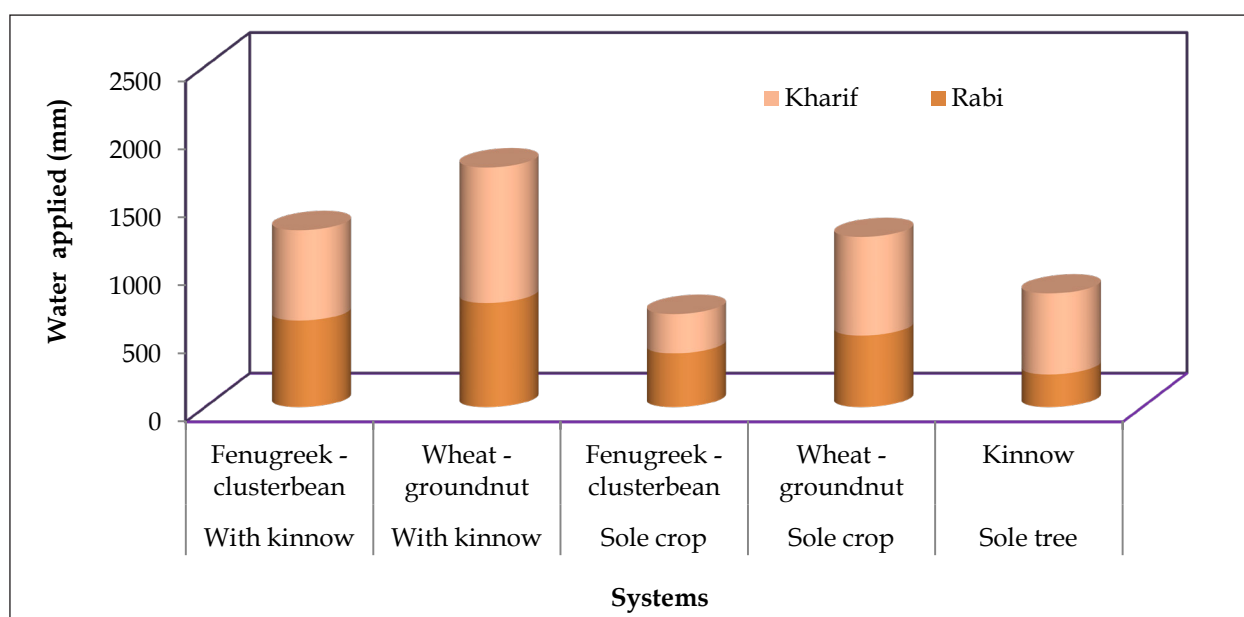


Fig. 1. Water applied in different kinnow based agri-horti and sole cropping systems.

Similarly, the annual increment in girth and canopy spread of kinnow was 11.8 and 11.6% with wheat-groundnut and 9.4 and 10.8% with fenugreek-clusterbean intercropping system as compared to 8.2 and 8.6%, respectively in sole kinnow. The improved growth attributes of kinnow in inter-cropping systems might be due to the reason that the intercrops modify the microclimate of the field which may help in active intake of nutrients and their partitioning. The intercropping systems help in efficient utilization of inputs by improving the input use efficiency of the system as compared to sole plantation where the interspaces were left uncultivated and did not receive any additional input in terms of fertilizer, supplemental

irrigation, additional biomass return through leaf litters etc. (Panda *et al.*, 2003; Shweta *et al.*, 2015). The positive effects of intercropping on vegetative growth of trees have also been reported by other researchers in citrus (Yadava *et al.*, 2013; Yadava *et al.*, 2017), sweet orange (Pal and Tarai, 2015), aonla (Awasthi *et al.*, 2009), ber (Saroj *et al.*, 2003; Yarangattikar and Itnal, 2003; Birbal *et al.*, 2013), mango (Rathore *et al.*, 2013) and pomegranate (Soni *et al.*, 2020).

Yield of kinnow

The fruit yield of kinnow was improved by intercrops as compared to sole kinnow tree, but it was non-significant. The fruit yield ranged between 5.20 and 5.43 t ha⁻¹ with the

Table 2. Growth performances of kinnow in kinnow based agri-horti system (values are $\pm$ standard error)

	2015	2016	% increase
	Height (cm)		
Sole kinnow	340 $\pm$ 2.26	365 $\pm$ 2.07	7.3
Kinnow + wheat-groundnut	345 $\pm$ 2.07	385 $\pm$ 2.76	11.5
Kinnow + fenugreek-clusterbean	350 $\pm$ 2.26	380 $\pm$ 2.40	8.5
	Girth (cm)		
Sole kinnow	46.4 $\pm$ 0.53	50.2 $\pm$ 0.52	8.2
Kinnow + wheat-groundnut	48.1 $\pm$ 0.41	53.8 $\pm$ 0.42	11.8
Kinnow + fenugreek-clusterbean	48.6 $\pm$ 0.34	53.2 $\pm$ 0.31	9.4
	Average canopy spread (cm)		
Sole kinnow	315 $\pm$ 1.47	342 $\pm$ 1.42	8.6
Kinnow + wheat-groundnut	318 $\pm$ 3.91	355 $\pm$ 2.68	11.6
Kinnow + fenugreek-clusterbean	315 $\pm$ 1.16	349 $\pm$ 1.20	10.8

highest yield with wheat - groundnut (5.43 t ha⁻¹) followed by fenugreek - clusterbean (5.32 t ha⁻¹) inter cropping system. The mean fruit yield was lowest in sole kinnow (5.20 t ha⁻¹). The positive effect of intercrops has also been observed on yield of ber fruits in arid region (Arya *et al.*, 2011; Gill *et al.*, 2018).

Yield of crops

A decrease in yield of both rabi and kharif season crops was observed in kinnow based intercropping system as compared to sole cropping (Table 3). There was a decline in 37% and 42% grain yield of wheat and fenugreek in rabi season crops and 37% and 44% grain yield of clusterbean and groundnut in kharif season crops grown in association with kinnow as compared to their sole cropping, respectively. A reduction in 41 to 49% straw yield was also observed in both seasons. The yield reduction of intercrops was due to the shading effect of system, reduced photosynthetic rate and sharing of important resources like light, moisture, nutrient, space etc. (Saroj *et al.*, 2004; Malik and Butola, 2010; Prasad, 2000).

System productivity

The annual system productivity was calculated in terms of grain clusterbean equivalent yield (CEY) (Fig 2). Sole kinnow showed minimum system productivity in terms of CEY (1.15 t ha⁻¹). This was due to the reason that kinnow was not in full bearing. It was in intermediate phase of its growth. System productivity was improved when kinnow was intercropped with fenugreek-clusterbean (2.95 t ha⁻¹) and wheat-groundnut (4.97 t ha⁻¹) intercropping. The share of kinnow and

intercrops in system productivity was 41.6 and 58.4 in kinnow + fenugreek-clusterbean and 24.4 and 75.6% in kinnow + wheat-groundnut intercropping system, respectively.

There were 2.56 and 4.33 times higher system productivity of kinnow + fenugreek-clusterbean and kinnow + wheat-groundnut intercropping system as compared to sole kinnow. The comparison of annual system productivity of sole annual crops and intercropping system of kinnow showed that the annual system productivity of intercropping system of kinnow + fenugreek-clusterbean (2.95 t ha⁻¹) was at par with the sole fenugreek-clusterbean system (3.03 t ha⁻¹). This shows that the area occupied by kinnow plantations and sacrificed by the non-sowing of intercrops was compensated by the kinnow yield. The study showed that intercropping system of kinnow is the better option in terms of annual system productivity over sole kinnow plantations during intermediate phase of fruit bearing of orchards.

Water use and water productivity

The water use was maximum in intercropping system of kinnow + wheat-groundnut (1759 mm) followed by kinnow + fenugreek-clusterbean (1299 mm) > sole wheat - groundnut (1249 mm) > sole kinnow (834 mm) > sole fenugreek - clusterbean system (683 mm) (Fig. 3). Water productivity in terms of economic yield (WP_{EY}) and biological yield (WP_{BY}) varied to the tune of 0.30 to 0.51 and 0.62 to 1.18 kg m⁻³, respectively. Intercropping systems of kinnow + fenugreek-clusterbean and kinnow + wheat - groundnut showed higher

Table 3. Grain and straw yield (t ha⁻¹) of different crops grown as sole and kinnow based agri-horti systems

Treatments	Yield (t ha ⁻¹)							
	Rabi				Kharif			
	Grain yield	Straw yield	Total dry matter yield	Fruit yield	Grain yield	Straw yield	Total dry matter yield	Fruit yield
Kinnow + wheat-groundnut	1.92	2.35	4.27	5.43	1.76	2.18	3.94	--
Kinnow + fenugreek-clusterbean	0.72	0.89	1.61	5.32	0.46	1.20	1.66	---
Sole wheat-groundnut	3.07	4.58	7.65	--	2.83	4.29	7.12	--
Sole fenugreek-clusterbean	1.25	1.52	2.77	--	0.83	2.35	3.18	--
Sole kinnow	--	--	--	5.20	--	--	--	--
LSD (0.05)	0.20	0.29	--	NS	0.24	0.23	--	--

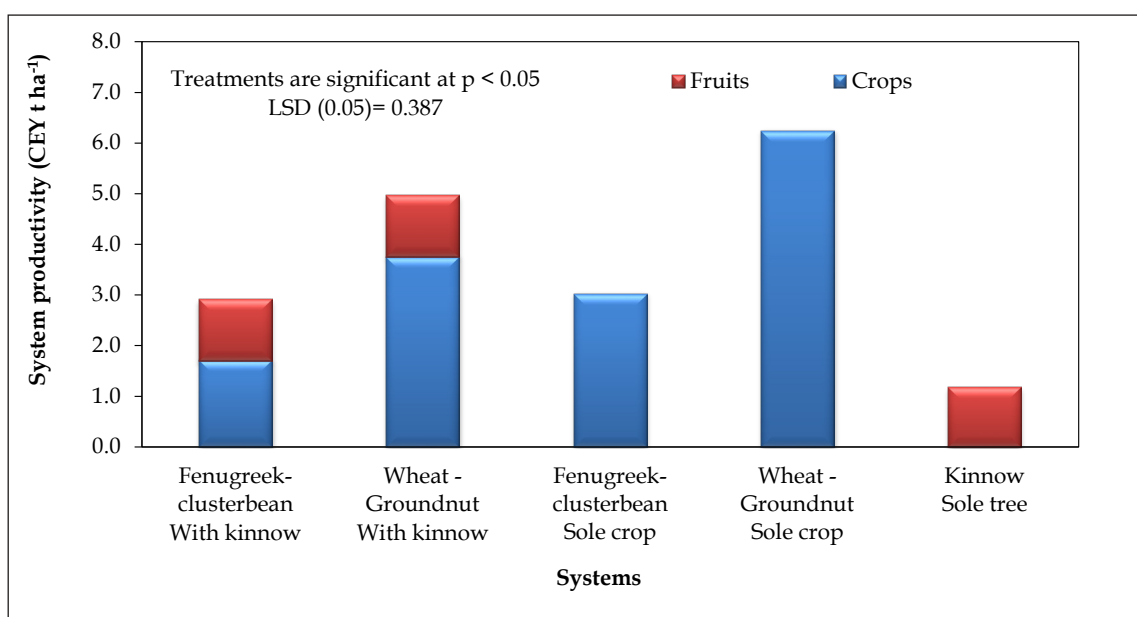


Fig 2. System productivity (Annual) in terms of grain clusterbean equivalent yield (CEY, $t ha^{-1}$) in different kinnow based agri-horti and sole cropping systems.

water productivity (WP_{EY}) as compared to their sole cropping (Fig. 3).

The water productivity in terms of gross return (WP_{GR}) ranged Rs. 4.99 to 17.49 m^{-3} (Fig. 4). The WP_{GR} increased from Rs. 4.99 m^{-3} in sole kinnow to Rs. 7.94 and 9.89 m^{-3} in kinnow + fenugreek - clusterbean and kinnow + wheat - groundnut intercropping systems, respectively. The higher WP_{GR} in intercropping system of

kinnow was due to the additional return from the produce of annual intercrops.

Economic returns

The cost of production returns and benefit cost ratio (BCR) of different systems are given in Table 4. The economic analysis of different systems showed that wheat-groundnut produced higher gross returns, net

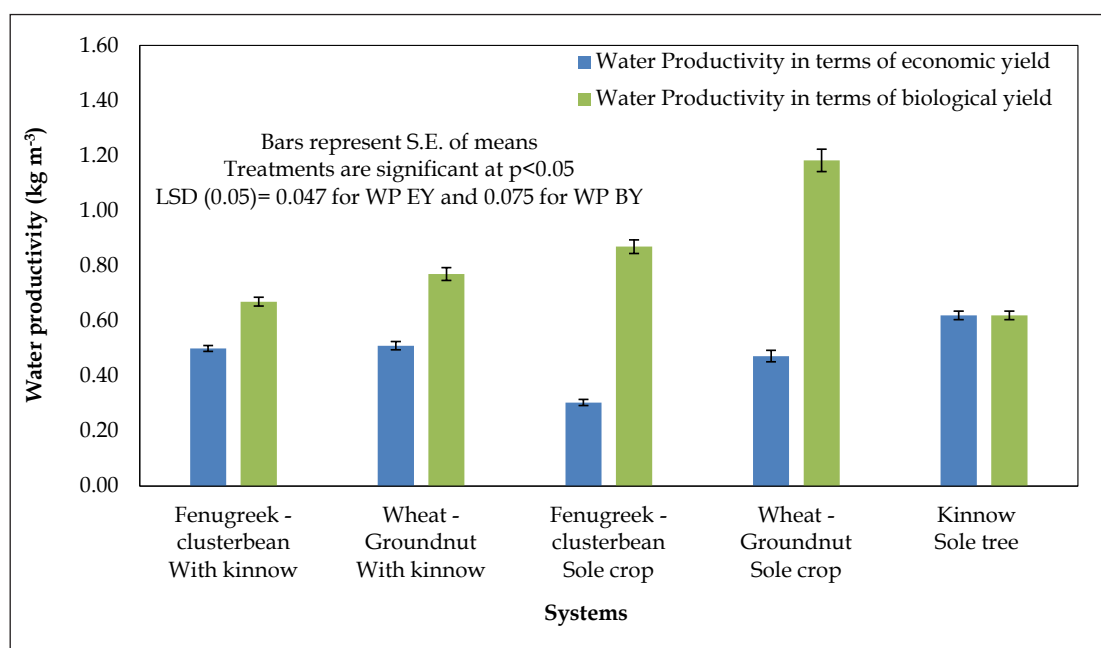


Fig. 3. Water productivity of kinnow based agri-horti and sole cropping systems in terms of economic yield (WP_{EY}) and biological yield (WP_{BY}).

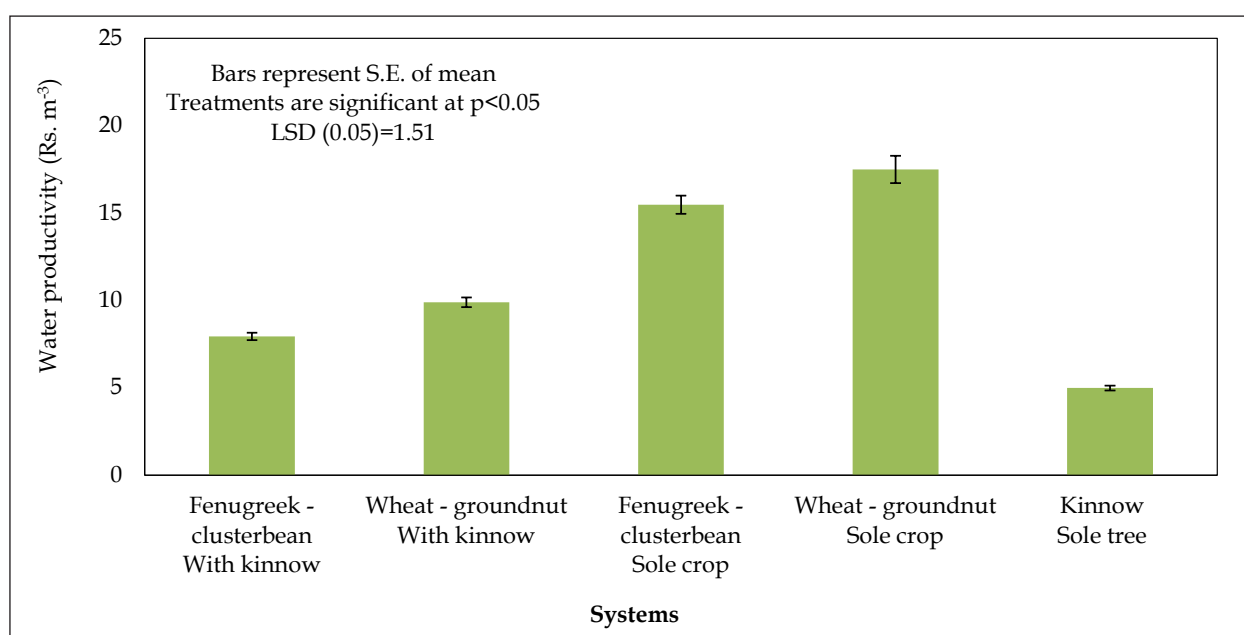


Fig. 4. Water productivity of kinnow based agri-horti and sole cropping systems in term of gross return (WP_{GR}).

return and BCR in sole cropping as well as intercropping system with kinnow over sole kinnow system. The gross returns, net return and BCR of intercropping systems were more as compared to sole kinnow. Wheat - groundnut rotation grown as intercropping with kinnow earned higher net returns (Rs. 82240 ha⁻¹), followed by fenugreek-clusterbean (Rs. 36160 ha⁻¹) intercropping system as compared to sole kinnow (Rs 13900 ha⁻¹). The share of intercrops in net return was 82.0 and 56.5% in kinnow + wheat-groundnut and kinnow + fenugreek - clusterbean intercropping system which indicated that the intercropping systems

of kinnow provides higher economic benefits through additional return from crop. When compared with sole kinnow, an additional income of Rs. 0.68 lakhs can be obtained with wheat-groundnut and 0.22 lakhs can be obtained with fenugreek - clusterbean intercropped with kinnow. The benefits of inclusion of intercrops has also been observed by other workers in various fruit crops (Ghosh and Pal, 2010).

Conclusion

From the above study, it may be concluded that intercropping systems promote the growth of kinnow, improve the annual

Table 4. Economic performance of different kinnow based agri-horti and sole cropping systems

Treatments	*Cost of production (Rs ha ⁻¹)			Gross return (Rs ha ⁻¹)			Net return (Rs ha ⁻¹)			B: C ratio
	Crops	Kinnow	Total	Crops	Kinnow	Total	Crops	Kinnow	Total	
Kinnow + wheat-groundnut	64040	27700	91740	131460	42520	173980	67420	14820	82240	1.89
Kinnow + fenugreek-clusterbean	39325	27700	67025	59740	43440	103180	20420	15740	36160	1.53
Sole wheat-groundnut	66440	--	66440	218540	--	218540	152100	--	152100	3.29
Sole fenugreek-clusterbean	40975	--	40975	105760	--	105760	64790	---	64790	2.58
Sole kinnow	--	27700	27700		41600	41600	--	13900	13900	1.50

*Cost of production includes only operational cost and does not include rental value of land, price of implements, interest on working capital etc.

system productivity, water productivity and returns. The farmers can get additional income through intercropping of wheat-groundnut and fenugreek-clusterbean in kinnow till the orchard comes under full bearing.

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