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Intercropping with vegetables on productivity and economic returns of Kinnow in arid region

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ABSTRACT

Experiments were carried out to study the productivity and economic performance of intercropping of Kinnow with vegetable crops. There were five treatment combinations *viz.,* (i) Kinnow + (Onion (*Allium cepa*)-Indian squash (*Citrullus lanatus* var. fistulosus), (ii) Kinnow + (Radish (*Raphanus sativus*- Cowpea (*Vigna unguiculata*), (iii) Sole Onion- Indian squash, (iv) Sole Radish- Cowpea and (v) Sole Kinnow. Intercropping showed positive effect on height, girth and canopy spread of Kinnow over its sole plantation. The fruit yield of Kinnow was significantly improved by intercrops as compared to sole Kinnow. However, the productivity of both *rabi* and *kharif* season crops was less with Kinnow as compared to sole cropping. The onion in *rabi* season and Indian squash in *kharif* season were better options for intercropping system in terms of crop yield equivalents as compared to sole Kinnow. The annual system productivity in terms of onion equivalent yield (OEY) was 2.81 and 7.58 times higher in Kinnow + (radish-cowpea) and Kinnow + (onion-Indian squash) as compared to sole Kinnow, respectively. Water productivity in terms of economic yield (WP_{EY}) was improved to 4.23 and 1.86 kg/m^3 in intercropping system of Kinnow + (onion –Indian squash) and Kinnow + (radish-cowpea) as compared to sole Kinnow (0.62 kg/m^3). Similarly, the water productivity in terms of gross return (WP_{GR}) was improved to 22.73 and 9.51 Rs/m^3 in Kinnow + (onion – Indian squash) and Kinnow + (radish-cowpea), respectively as compared to 4.98 Rs/m^3 in sole Kinnow. The B: C ratio of Kinnow + (onion-Indian squash) and Kinnow + (radish-cowpea) was improved to 3.65 and 2.06, respectively, as compared to sole Kinnow (B: C ratio of 1.50).

Key words: Intercropping, kinnow, water productivity, vegetables, arid zone

INTRODUCTION

Thar desert of Rajasthan occupies major part of north-western India (28.7 m ha). The region is characterised by extremes of climatic conditions with low rainfall and high temperature. The soils of the region are poor in organic matter, low in clay and silt, and poor in nutrient availability (Kumar *et al.*, 8). Yield losses associated with water stress and soil erosion are common in this zone (Soni *et al.* 14; Soni *et al.*, 15; Santra *et al.*, 12). With the inception of irrigation facility through Indira Gandhi Nahar Pariyojana (IGNP), growing of suitable group of citrus fruits such as Kinnow, acid lime and sweet orange are now becoming popular and their area is increasing day by day.

Kinnow a mandarin hybrid, is gaining popularity among the fruit growers of Khajuwala, Chattargarh and Charanwala area of Bikaner district having irrigation facility. The crop has a great potential for its expansion due to consumers preference, high yield and better economic returns. Kinnow growers also grow few vegetable crops as sole crop which however, can also be grown as intercrop with Kinnow mandarin. Growing suitable vegetables as intercropping with fruit trees will make the system more economic to the farmers in terms of generating extra income, enhancing productivity per unit area and time, and improve ecological situation. Though intercropping of trees with suitable vegetables seems remunerative, yet meager scientific information is available regarding production, water productivity and economics of Kinnow based oleri-horti system in western part of Rajasthan. Previous studies conducted in other parts of India revealed that the economy of Indian farmers can be improved through intercropping systems in sweet orange (Ghosh and Pal, 16) and Kinnow (Bhatnagar *et al.*, 3). There is hardly any systematic research work on growing fruit trees with vegetable crops in arid regions of Rajasthan. Hence, the present experiment was conducted to assess the yield, water productivity and economic performance of Kinnow based oleri-horticultural systems in hyper arid partially irrigated zone of western Rajasthan.

MATERIALS AND METHODS

The study was carried out 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) during *rabi* and *kharif* seasons 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

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conditions. The region receives around 250 mm rainfall, 75% of which is received from the South-West monsoon during July–September. Potential evapo-transpiration 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 soil of the experimental site was loamy sand, low in 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 1.46 to 1.52 Mg m^{-3}, 4.8-7.6 cmol (p^+)/ kg^1, 7.7 to 8.2, 0.05 to 0.07 m^3/ m^3 and 0.12 to 0.18 $m^{3/}m^3$, respectively. The soil organic carbon (SOC) and FC decreased, whereas pH and BD increased with increasing soil depth. Soil available N and P decreased with soil depth and were in low and medium category. Available potassium was more in upper profiles and decreased with soil depth (Table 1).

The experiment was conducted during *rabi* and *kharif* seasons of 2015-16 and 2016-17, respectively in seven years old plantations of Kinnow mandarin spaced at 8 m × 6 m apart. In the interspaces of Kinnow, the crops were sown in a plot size of 6 m×12 m in randomized block design 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:

T_1: Kinnow + Onion (*Var. Nasik red*)- Indian squash (*Selection-1*)

T_2: Kinnow + (Radish (*Var. Ivory white)*- Cowpea (*Var. RC-19*)

T_3: Sole Onion (*Var. Nasik red*) - Indian squash (*Selection-1*)

T_4: Sole Radish (*Var. Ivory white*)- Cowpea (*Var. RC-19*)

T_5: Sole Kinnow

The recommended packages of practices were followed for Kinnow and intercrops. Kinnow trees were irrigated by making basins around the plants and intercrops were irrigated with sprinkler irrigation system. The total amount of irrigation water applied in the system (irrigation + rainfall) has been shown in Fig 1b. Plant protection measures and intercultural operations were done as and when required for both the crop components.

Physico-chemical properties of the soil were analyzed by their standard procedures (Jackson, 10). The growth and yield of Kinnow and intercrops were recorded during the experimentation period. System productivity was calculated in terms of onion equivalent yield (OEY) on the basis of selling price of each produce using equation-1. The OEY of individual components (intercrops of both seasons and fruit yield) was summed up to obtain overall system productivity of individual treatments.

$$\text{OEY (kg ha}^{-1}) = \frac{\text{Yield of intercrops (kg/ha)} \times \text{Selling price (Rs/kg)}}{\text{Selling price of Onion (Rs/kg)}} \quad \text{....Eq 1}$$

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

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

The economic analysis was carried out by considering the actual expenditure incurred on various operations, labor charges, prevailing market price of inputs and crop produce. The benefit: cost ratio was calculated dividing gross returns by the cost of cultivation of individual treatment. The data recorded on various attributes were subjected to Fisher's method of analysis of variance and interpretation of data was taken up as per Sukhatme and Amble (16).

RESULTS AND DISCUSSION

Intercropping of different vegetables was found to have a positive effect on plant height, stem girth and average canopy diameter of Kinnow over its sole crop (Table 2). Average annual increase in height of Kinnow with radish-cowpea and onion-Indian squash inter-cropping system was 11.7 and 14.9 %, respectively, as compared to 7.3 % in sole Kinnow. Similarly, the increase in girth and average canopy diameter of Kinnow was 9.3 and 10.3 per cent with radish-cowpea, and 11.1 and 13.8 per cent with onion-Indian squash cropping system as compared to 8.2 and 8.5 per cent in sole Kinnow, respectively. This might be due to the fact that adoption of intercropping systems in Kinnow helps in efficient utilization of natural resources as well as it improves the input use efficiency in the system than sole plantation

Table 1. Physico-chemical properties of soil of experimental plot.

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	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

Table 2. Growth of Kinnow as affected by different intercrops in oleri-horti system (Values are ± standard error).

Treatment	2015	2016	Per cent increase over previous year
		Height (cm)	
Sole Kinnow	340±2.26	365±2.07	7.3
Kinnow + Radish-Cowpea	340±2.11	380±2.11	11.7
Kinnow +Onion-Indian squash	335±2.27	385±2.27	14.9
		Girth (cm)	
Sole Kinnow	46.4±0.53	50.2±0.52	8.2
Kinnow + Radish-Cowpea	47.9±0.53	52.4±0.41	9.3
Kinnow +Onion-Indian squash	49.4±0.35	54.9±0.38	11.1
	Canopy diameter (cm)		
Sole Kinnow	315±1.47	342±1.42	8.5
Kinnow + Radish-Cowpea	320±1.21	353±1.23	10.3
Kinnow +Onion-Indian squash	318±1.48	362±1.39	13.8

where the interspaces were left uncultivated and did not receive any additional input in terms of fertilizer, supplemental irrigation, additional biomass through leaf litters etc. Since the experimental soil was very low in soil organic carbon and nitrogen (N), hence a small amount of additional source of N helped in better growth and development of plants. The positive effects of intercropping on vegetative growth have been reported by other workers in citrus (Yadava *et al.* 17; Yadava *et al.,* 18), sweet orange (Pal and Tarai, 10), aonla (Awasthi *et al*., 2) and pomegranate (Soni *et al*., 13).

The fruit yield of Kinnow was significantly higher when grown with intercrops as compared to sole plantation of Kinnow. The fruit yield ranged between 5380 and 5560 kg/ha having maximum yield in Kinnow + onion- Indian squash (5560 kg/ha) followed by Kinnow+radish-cowpea (5470 kg/ha). The mean fruit yield was less in sole Kinnow (5380 kg/ha) as compared to intercropping systems. The positive effect of intercrops on yield of ber fruits in arid region have also been reported by Arya *et al.* (1).

Productivity of both *rabi* and *kharif* season crops was less with Kinnow as compared to sole cropping. Due to the detrimental effect of partial shade, total yield further declined. The yield of crops *viz*., onion (30800 kg/ha) and radish (17100 kg/ha) in *rabi* season and Indian squash (19500 kg/ha) and cowpea (245 kg/ha) in *kharif* season was significantly less in Kinnow based intercropping system as compared to sole cropping. The onion in rabi season and Indian squash in kharif season were least affected in inter cropping system with Kinnow. The straw yield of cowpea (695 kg/ha) was more in sole cropping as compared to Kinnow based intercropping system (328 kg/ha) (Table 3). The yield reduction of intercrops was due to the shading effect of system and sharing of important resources like light, moisture, nutrient, space etc. (Bremner, 4; Buck, 5) and reduced photosynthetic rate (Prasad *et al*., 11).

The annual system productivity was calculated in terms of onion equivalent yield (OEY) (Fig 1a). Sole Kinnow produced minimum OEY (8.32 t/ha). There were 2.81 and 7.58 times higher system productivity of Kinnow + (radish-cowpea) and Kinnow + (onion-Indian squash) as compared to sole Kinnow. This was due to the reason that the sole Kinnow was in intermediate phase of its growth and was not in full bearing. The annual system productivity of inter-cropping system of Kinnow + (onion-Indian squash) (63.1 t/ha) was at par with the sole onion-Indian squash system (66.1 t/ha). Similarly, OEY of intercropping of Kinnow+ (radish-cowpea) was also at par (23.4 t/ha) with sole radish-cowpea system (24.3 t/ha). This shows that the reduced yield of intercrops through the area sacrificed by the non- sowing of intercrops was compensated by the Kinnow yield which was in the intermediate phase of its growth. The study showed that Kinnow+ onion –Indian squash was better option in terms of annual system productivity over sole Kinnow plantations during intermediate phase of fruit bearing of orchards.

The maximum amount of water was applied in intercropping system of Kinnow + Onion-Indian squash system (1320 mm) followed by Kinnow + radish-cowpea intercropping system (1229 mm), sole Kinnow (834 mm), sole onion-Indian squash (704 mm) and minimum in sole radish-cowpea system (623 mm) (Fig 1b). Water productivity in terms of economic yield (WP_{EY}) varied from 0.64-8.75 kg/m^3. Among all the treatments, sole onion-Indian squash showed highest WP_{EY} (8.75 kg/m^3). Sole Kinnow showed minimum WP_{EY} (0.62 kg/m^3) (Fig 1c). Water productivity (WP_{EY}) was improved when intercrops were introduced in Kinnow plantations. Intercropping of onion –Indian squash and radish-cowpea with Kinnow improved water productivity to 4.23 and 1.86 kg m^{-3} as compared

Table 3. Yield of different crops grown as sole and in association with Kinnow trees (Pooled mean for two years).

Treatments	Yield (kg ha^{-1})					
	Rabi			Kharif		
	Grain/ Veg yield	Straw yield	Fruit yield	Grain/ Veg yield	Straw yield	Fruit yield
Kinnow + Onion- Indian squash	30800 ± 1000	--	5560 ±136	19500 ± 727	---	--
Kinnow + Radish- Cowpea	17100 ±745	--	5470 ±143	245 ± 7.4	328 ± 12	---
Sole Onion- Indian squash	39100 ±1534	--	--	22500 ± 1224	--	--
Sole Radish- Cowpea	26300 ± 973	--	--	470 ±25	695 ± 26	--
Sole Kinnow	--	--	5200 ±147	--	--	--

Values are ± standard error

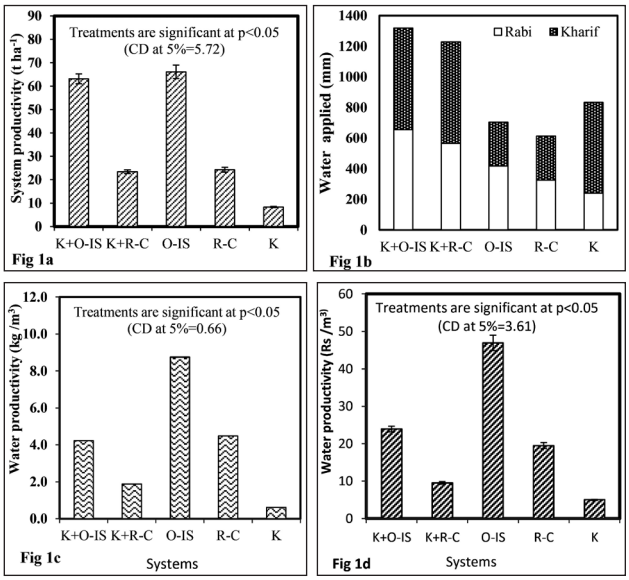

Fig. (1a). Water applied in different Kinnow based oleri-horti and sole cropping systems, **(1b)**. System productivity (Annual) in terms of onion equivalent yield (OEY, t/ha), **(1c).** Water productivity in terms of economic yield, **(1d).** Water productivity in term of gross return in different Kinnow based oleri-horti and sole cropping systems.

(K+O-IS=Kinnow+ Onion - Indian squash, K+R-C=Kinnow+ Radish – Cowpea, O-IS= Sole Onion - Indian squash, R-C= Sole Radish – Cowpea, K= Sole Kinnow)

to sole Kinnow (0.62 kg/m^3). The water productivity in terms of gross return (WP_{GR}) varied from 4.99 to 46.92 Rs/m^3 (Fig 1d). Sole Kinnow registered minimum WP_{GR} (4.99 Rs/m^3) which can be improved to 9.51 and 23.90 Rs/m^3, respectively through intercropping of Kinnow + (radish-cowpea) and Kinnow + (onion – Indian squash).

The cost of production and returns of the inter crops in association with Kinnow and sole crops are given in Table 4. Economic analysis of different cropping system showed that Onion-Indian squash produced more returns in sole crops as well as intercropping system over sole Kinnow. The B:C ratio of intercropping system was more as compared to sole Kinnow. When compared with sole Kinnow, an additional income of Rs. 2.15 lakhs can be obtained with Onion-Indian squash and Rs. 0.46 lakhs can be obtained with radish-cowpea intercropped with Kinnow. The benefits of inclusion of vegetables as intercropping has also been observed by other workers in various fruit crops (Ghosh and Pal, 6; Malik and Butola, 9).

From the results of present study, it can be concluded that inclusion of intercrops in the left over spaces of Kinnow plants can improve the tree growth of Kinnow, annual system productivity, water productivity and economic returns.

AUTHORS' CONTRIBUTION

Conceptualization of research (M.L. Soni, V. Nangia and N. D. Yadava); Designing of the experiments

Table 4. Economic performance of different systems grown as sole and in oleri-horti system (Pooled mean for two years).

Treatments	*Cost of production (Rs/ ha)	Gross return (Rs/ ha)	Net return (Rs/ ha)	Net gain/loss over sole Kinnow	B:C ratio
Kinnow+ Onion-Indian squash	86400	315480	229080	215180	3.65
Kinnow + Radish - Cowpea	56600	116956	60356	46456	2.06
Sole Onion-Indian squash	58700	330500	271800	257900	5.63
Sole Radish - Cowpea	28900	121365	92465	78565	4.19
Sole Kinnow	27700	41600	13900	---	1.50

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

(M.L. Soni, Birbal and N. D. Yadava); Contribution of experimental materials (A. Saxena and N. D. Yadava); Execution of field/lab experiments and data collection (M.L. Soni and Birbal); Analysis of data and interpretation (M.L. Soni, Birbal and N. D. Yadava); Preparation of the manuscript (M.L. Soni and Birbal).

DECLARATION

The authors declare no conflict of interest

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