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Research article

Fodder and fruit production for livelihood security in agri-horticultural system: an on-farm study

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Abstract

On-farm field trial was conducted under rainfed conditions of Jammu region for three consecutive years with fodder crops taken as intercrops in agri-horticultural systems. Fodder crops (maize and bajra) were integrated with *Eureka lemon* (Lemon) or *Kinnow mandarin* (Kinnow). Multipurpose trees (MPTs) were also planted on the borders of the field. The study indicated enhanced growth of citrus along with maize and bajra as intercrops. Maize and bajra crops provided both green and dry fodder along with grain for human consumption, thus providing extra income to the farmer from same land unit. Net returns as well as B:C ratio were higher when bajra was intercropped either with *Eureka lemon* (Lemon) or *Kinnow mandarin* (Kinnow) as compared to maize iintercropping. Intercropping of maize and bajra also showed remarkable effect on fruit size (length and diameter) and fruit quality (total soluble solids, reducing sugar, total sugar and ascorbic acid). The weight and size of *K. mandarin* and *E. lemon* fruits were more when intercropped with bajra and maize in comparison to sole fruit trees. The multipurpose trees on the border areas of the farm helped to save land and increase cropping area.

Keywords: Agri-horticultural systems, Bajra, Citrus, Maize, Multipurpose trees

Introduction

Indian economy being predominantly agrarian, in last three decades has made rapid strides in food production, culminating in self-sufficiency and surplus production. However, feeding the ever-increasing population through the next millennium remains an uphill task. The country will have to feed about 1.4 billion people by the year 2030 requiring 5-6 mt of additional food grains every year (Anonymous, 2011). Rainfed agriculture occupies 67% of net sown area, contributing 44% of food grain production and supporting 40% of human population and 65% of the livestock population (Venkateswarlu and Prasad, 2012). Livestock forms an integral part of rainfed ecosystem and two out of every three animals are thriving in these regions. Forage production is the backbone of livestock industry in India. The scarcity of green forages and grazing resources in the country has made the livestock to suffer continuously with malnutrition resulting in their production potentiality at suboptimum level as compared to developed nations (Gupta *et al*., 2019; Mahanta *et al.,* 2020). The annual forage requirement of our country is 1410 million tonnes (880 million tonnes green and 530 million tonnes dry). The present feed and fodder resources of the country can meet only 48% of the requirement with a vast deficit of 32 and 23% of green and dry fodder, respectively (Anonymous, 2020).

Increasing crop productivity to meet food, fodder, fuel, timber and fruit requirements is a great challenge, therefore, cultivation has to be extended to other available lands like orchards. Intercropping of botanically diverse forage species like cereals and legumes appear to be one of the feasible approaches for increasing the herbage yield, utilization of land more efficiently, improving the forage quality and providing stability to production (Kumar *et al*., 2014). Horticulture-based production system has been found effective in improving productivity, providing employment opportunities and nutritional security besides enhancing socio-economic status. Several drought hardy fruit trees like *Capparis decidua, Salvadora oleoides, Cordia dichotoma, Ziziphus nummularia* var. *rotundifolia*, *Zizypus mauritiana* are suitable for the areas receiving less rainfall. Besides providing fruits, these plants produce moisture laded

nutritious leaves as fodder for animals (Kumar *et al*., 2019). Eureka lemon (*Citrus limon Burm)* has become an important fruit crop of rainfed areas of the country because of its precocity, thornlessness and heavy bearing nature (Kumar *et al*., 2016). *Kinnow mandarin*, a hybrid cultivar of citrus developed by crossing King (*Citrus nobilis*) with Willow leaf (*Citrus deliciosa*) is extensively grown in Punjab and Rajasthan states of India. However, the success of intercropping in orchard depends mainly on selection of suitable intercrop as the pre harvest management practices influence the kinnow fruit growth (Din *et al*., 2012). The optimum sowing time of intercrops ensures complete harmony between the vegetative and reproductive phases on one hand and the climatic rhythm on the other and help in realizing the potential yield. It was observed that sowing maize in citrus orchard helped to improve the predators' population that controls citrus leaf miner (Ahmed *et al.*, 2013).

The intercrops in the form of fodder not only generated an extra income but also helped to check the soil erosion through ground coverage and improved the physico-chemical properties of the soil (Bhatanagar *et al*., 2007; Swain, 2014). Further, fodder trees played an important role in reducing problem of fodder shortage in India. Multi-purpose trees (MPTs) like *Leucaena leucocephala*, *Grewia optiva, Celtis australis*, *etc.* in western Himalayas are able to withstand the drought, stay green, and provide a nutritious fodder for livestock (Ram *et al*., 2016). In the present study, the inter row space in citrus orchard (*Eureka lemon* and kinnow *mandarin*) location specific fodder crops were grown as intercrops, to ensure efficient use of resources along with introduction of new varieties of fodder and modern technology. Thus, there was a need to identify suitable intercrop which remains compatible throughout the growth of main crop. Therefore, this study aimed to assess the impact of intercropping on *Eureka lemon* and Kinnow *mandarin* yield, fruit quality and economic aspect.

Materials and Methods

Study area: The study was conducted on farmers' field of a farmer, village Satauh, Jammu region. Various benefits of growing fodder and other crops at orchard were explained to him and encouraged to undertake all the planned research activities in his orchard. After few meetings, he agreed to grow the crops in between the alleys of his kinnow and lemon orchard. The orchard had four years old citrus trees, planted in an area of about 1.0 ha at a distance of 4m x 4m. Total number of trees was 164 of which 80 trees are of kinnow and 84 of lemon.

Climate and soil: About 12% of the total area of Jammu region constitutes dry semi-hilly belt is rainfed in nature, the most stressed ecosystem of this region and is locally known as *kandi* area (Gupta *et al*., 2014). The region is well recognized for the cultivation of fruits as well as field crops both under irrigated and rainfed conditions and enjoys sub-tropical climate with hot summer, and cold winter seasons. Average monthly maximum and minimum temperature for the citrus growing period of October to March varied between 13.0 to 34.3°C and 2.9 to 20.7°C, respectively. The climate of this region is influenced by south-west monsoon in *kharif* and western disturbances in *rabi* seasons. The mean annual rainfall of the region is about 1150 mm out of which nearly 75% of the total annual rainfall is received during the southwest monsoon, from the first week of July to the middle of September and rest during winters through western disturbances.

Agronomic interventions and observations made: Crops like bajra and maize raised for both fodder as well as grain were intercropped in the inter-row spaces of the orchard to meet the food and fodder requirement of the family.The intercrops were sown 1 m away from the fruit trees on either side of the trunk leaving an area of 3.14 m^2 around each tree. Bajra and maize sowing was done with the onset of monsoon. Bajra crop grown for multi-purpose as the green fodder was harvested 35-40 days after sowing (DAS) and thereafter, urea @ 35 kg ha^{-1} was applied to the crop and again green fodder was harvested about 25-30 DAS. After taking two green fodder cuts the crop was allowed for grain formation with application of additional dose of urea @ 35 kg ha^{-1} and then harvested for grain as well as stover. Maize crop was also planted for grain as well as green fodder; after harvesting cobs the stover was used as fodder for cattle.

For economic evaluation of the system, the cost items included the cost of plants, labour charges for digging pits, planting and training of trees, charges for ploughing the field, field preparation and for cultivation of crops, material inputs such as seed and fertilizer, labour cost for different field operations, harvesting and threshing charges of crops. The prevailing market rates of the crops (grain + straw) and fruits in the respective years were taken into account to work out the gross and net returns. Proper scientific care and management of fruit trees was done as per the package and practices of SKUAST-

Jammu. Pre-sowing and post-harvest samples from the experimental plots were collected. The soil samples were air-dried, thoroughly mixed and ground to pass through a 2 mm sieve. Soil pH and organic carbon were estimated by the methods suggested by Jackson (1973). Soil available N, P and K were determined by following the methods of Subbiah and Asija (1956), Olsen *et al.* (1954) and Merwin and Peech (1950), respectively.

Multipurpose trees (MPTs): The multipurpose trees (MPTs) planted on the borders of the field helped to save land and increase cropping area. MPT like *Leucaena leucocephala* was grown on the borders/hedges of the farmer's farm land which was earlier unutilized; however, a few trees of *Leucaena leucocephala* were also growing naturally on the farm land/borders. The *Leucaena leucocephala* trees were lopped at the height of 1.5 m above the ground three times a year. The green leaves obtained from lopping were used as fodder for farmer's cattle and goat, fuel wood for house hold use besides getting some additional income from sale of wood.

Fruit yield and physico-chemical characteristics: The average weight of fruit was calculated by selecting ten fruits at random. Fruit length and breadth of these randomly selected fruits was measured with the help of digital vernier calipers. Average fruit weight (g), length (cm) and width (cm) were measured at harvest. Different segments from each fruit sample were taken, squeezed and the juice obtained was used to determine the percentage of total soluble solids (TSS) by hand Refractometer. Total sugars, reducing sugars, acidity and ascorbic acid content were measured according to the standard procedure of Ranganna (1986). The fruit yield of Kinnow and *Eureka lemon* was estimated by multiplying the total number of fruits per tree to the average fresh weight of fruits during harvesting and expressed as kg tree^{-1}and then converted to q ha^{-1}. The rates of fruits and different crops were considered as per the market rates. Maize equivalent yield (MEY) was calculated on the basis of current market rates of fruits, maize and other respective crops for the different years of study as:

MEY = (Yi × Pi)/ P(p); where MEY was maize equivalent yield; Yi was yield of different crops/components; Pi was price of respective crops/components and P(p) was price of maize crop.

Land equivalent yield (LER): Land equivalent yield was calculated as sum of total of the ratios of yield of each component crops in an intercropping system or a mixed cropping system to its corresponding yield when grown as a sole crop.

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where Yab was the yield of species 'a' in association with species 'b', and Yba was the yield of species 'b' in association with species 'a', Yaa and Ybb represented the pure stand yields of species 'a' and 'b', respectively.

Results and Discussion

Fruit and fodder yield: Both fruit and fodder crops yields were much higher than nearby farms which was due to scientific interventions like use of hybrid seeds, application of recommended dose of fertilizers and manures to the fruit trees as per age of tree and foliar application by micro-nutrients, timely pest management, *etc*., carried out during the study period. Fruit yield of selected farmer's field was 21.0% higher than nearby farms. Fruit yield of Kinnow was 14.8% higher than lemon yield. Grain and stover yield of both maize and bajra as well as green fodder yield of bajra were lower when intercropped than that obtained in their pure stand as sole crops, whereas fruit yield of both lemon and Kinnow was higher under intercropping than their pure stand (Table 1). Mean green fodder yield of maize and bajra when intercropped in fruit trees was 53.0 and 48.0% lower than their respective sole crops. However, under intercropping fruit yield of lemon was 13.6% and that of Kinnow was 6.6% higher than their pure stand. Fodder yield of bajra was 206% higher than maize as three fodder cuts were taken in bajra. Both fruit and crop yield were also expressed as maize equivalent yield (MEY) both on grain and fodder basis and it was observed that highest grain MEY (64.01 q/ha) recorded in Kinnow + maize followed by lemon + maize (60.56 q /ha) and the lowest was found in sole bajra. Contrarily, MEY on fodder basis was found to be highest (34.14 q/ha) in sole bajra followed by Kinnow + bajra and the lowest values recorded in sole maize. However, maize crop produced higher grain yield (34.7 q/ha). These crops provided additional income to farm family which helped farmer to meet his small revenue demands. Similar benefits of intercropping in fruit trees which provided additional income to the small and marginal farmers were also reported by Ramana *et al*. (2011) and Gupta *et al*. (2020).The land unit was also used efficiently which was evident from the higher land equivalent ratio (LER) values under intercropping systems. Higher LER values were observed when bajra was intercropped with lemon followed by maize

Table 1. Yield, economics and LER under different treatments of agri-horti system

Treatments	Fruit yield (q/ha)	Green fodder (q/ha)	Stover yield (q/ha)	Grain yield (q/ha)	Grain MEY (q/ha)	Fodder MEY (q/ha)	LER	Cost of cultivation (Rs/ha)	Net returns (Rs/ha)	B:C ratio
E. lemon	20.10	-	-	-	33.27	-	-	15210	45090	2.96
Kinnow	23.08	-	-	-	38.21	-	-	15210	3050	2.03
E.lemon + bajra	22.74	165*	28.13	13.4	50.71	24.64	1.76	32672	92595	2.83
E.lemon +maize	22.95	-	42.4	21.8	60.56	-	1.76	38881	69247	1.78
Kinnow+bajra	24.96	176*	30.9	15.0	56.02	26.36	1.72	32672	79279	2.42
Kinnow+maize	24.35	-	49.8	24.4	64.01	-	1.68	38881	54133	1.40
Sole bajra	-	225	43.7	21.0	20.5	34.14	-	17466	65169	3.73
Sole maize	-	-	70.3	34.7	34.7	6.98	-	23771	38171	1.65

*It includes both cuttings of green fodder; MEY: Maize equivalent yield; LER: Land equivalent ratio

intercropped with lemon, which helped to increase both productivity and profitability.

Fodder trees: The lopping of *subabul* was done thrice a year; the maximum quantity of green leaves and dry wood was obtained during the 1st cut *i.e.,* after the withdrawal of *monsoon* in September/October month followed by 2nd and 3rd cuts (Table 2). This might be due to luxurious growth of *subabul* trees during the rainy season and slow growth during winter because of lower temperature and less rainfall. Also, green leaves lopped during 2nd and 3rd cut fetched higher price because of the higher demand and low availability of green fodder during that period especially in rainfed areas. Similar trend was observed for the local growing fodder trees but the yield of green leaves and fuel wood was less as compared to the higher green forage yield of *subabul*. In many farm households, production of tree resources was not a principal livelihood source, but it was a complementary alternative. However, farm tree resources were exploited by all the categories of natives in the society and the income earned was an indispensable source of self-respect, pride and self determination. Islam *et al.* (2021) observed similar results that household farm was the valuable source of many tree resources like fuel wood, tree browse, timber, wicker, fruits and leaf litter, which were of great significance for household livelihoods and was key contributor to financial well being, accounting for 16.23% of the total household income. Leaves/twigs and wood obtained by the regular lopping of fast growing and nitrogen fixing tree *subabul* (*Leucaena leucocephala*) were also used as fodder for animals and fire wood, respectively in rainfed areas (Ram *et al.,* 2016).

Fruit quality and yield attributes: The intercropping of maize and bajra had a prominent effect on fruit size (length and diameter) and various quality parameters like total soluble solids, reducing sugar, total sugar and ascorbic acid. The weight and size of *Kinnow mandarin* and *Eureka lemon* fruits were more when intercropped with bajra and maize in comparison to sole fruit trees (Table 3). It might be attributed to vigorous growth and developments of fruit trees under intercropping. Higher fruit TSS and other quality parameters under intercropping treatments were well related to higher moisture conservation and maximum nutrient uptake under intercropping with bajra and maize crops, as there was no physical barrier between the root systems of intercrops and trees. The reason for increase in fruit production could also be attributed to synergistic effect of the

good crop husbandry during the crop growing season which might have resulted in lower insect and disease incidence in the citrus plants. These results were in conformity with the findings of Kumar *et al*. (2016) in *Eureka lemon* under *kandi* conditions of Jammu. Gill *et al.* (2018) also reported higher TSS content under intercropping system in Kinnow fruit. Similar results were also observed by Swain (2014) in terms of fruit quality in mango. The results also corroborated with the findings of Bakshi *et al*. (2015). The higher yield advantages particularly average fruit weight (g) and fruit yield (q/tree) under intercropping systems were mainly attributed to efficient utilization of natural resources like solar radiation, soil moisture and nutrients because of complementary interaction between the component crops (Gill *et al*., 2018). Swain (2014) also observed a significant increase in fruit yield of mango under various intercropping treatments. Gajja *et al.* (2004) viewed that horti-pasture system were more profitable than arable cropping under arid condition and they revealed that horti-pasture comprising *Ber* and *C. ciliaris* were economically viable on the basis of B:C ratio, net present worth and annuity value at 10% rate of interest under arid ecosystem.

In rainfed regions, where the build-up of organic matter is limited, nitrogen-fixing trees offer immense possibilities of supplying organic matter, conserving soil moisture and supplementing the nitrogen needs of crops. Also the benefits of intercropping fodder crops in fruit orchard was observed from the second year onwards, as it was effective in bringing about

Table 2. Green leaves/fodder and fuel wood yields (q/ha) of fodder trees (mean of three years)

Fodder trees	Fresh leaves/fodder*			Fuel wood*		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
Subabul	45.80	29.60	18.20	27.50	16.20	11.70
Other local fodder trees	28.10	17.70	11.90	19.20	11.30	8.20

*Trees lopped 3 times in a year *i.e.*, 1st cut-after withdrawal of *monsoon* (September/October), 2nd cut after winter season (February/March) and 3rd cut-before onset of *monsoon* (May/June); Rate of green leaves: 1st cut) = Rs. 50/q, 2nd and 3rd cut = Rs. 75/q, fuel wood = Rs. 150/q

Table 3. Effect of intercrops on physico-chemical characteristics of *Eureka lemon* and *Kinnow mandarin* fruit in agri-horti-system (mean of 3 years)

Treatments	Fruit weight (g)	Fruit length (cm)	Width (cm)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100 ml)	Total sugars (%)	Reducing sugars (%)
E. lemon	62.0	4.85	4.68	6.0	5.08	37.0	2.26	1.50
E. lemon + bajra	63.0	4.97	4.90	6.9	5.02	37.86	2.60	1.95
E. lemon+ maize	62.5	4.90	4.75	6.4	5.05	37.60	2.40	1.70
Kinnow mandarin	102	5.0	6.1	11.0	1.45	20.0	8.20	5.4
K. mandarin + bajra	105	5.4	6.5	11.9	1.40	21.6	8.90	6.0
K. mandarin + maize	103	5.2	6.3	11.5	1.43	20.9	8.26	5.8

Table 4. Soil fertility status after three years of interventions in agri-horti system

Treatments	OC (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Eureka lemon	0.28	0.335	149	180	8.7	10.8	84.2	91.0
Kinnow	0.28	0.338	148	182	8.8	9.2	84.4	91.6
Eureka lemon+ bajra	0.27	0.339	151	183	8.9	9.1	86.5	92.4
Eureka lemon+ maize	0.29	0.342	152	180	9.2	10.4	84.7	93.0
Kinnow + bajra	0.28	0.341	155	185	9.1	10.8	86.4	92.6
Kinnow + maize	0.29	0.344	152	188	9.3	10.6	85.4	92.6
Sole bajra	0.26	0.335	148	183	8.1	10.8	84.4	91.1
Sole maize	0.26	0.338	147	182	8.2	9.2	84.6	91.2

improvement in the soil properties as reflected by the increase in organic carbon, available nitrogen, phosphorus and potassium (Table 4).

Income benefits: Data presented in (Table 1) clearly showed the effect of intercropping and agronomic interventions on fruit and crop (maize and bajra) yields. The increase in crop and fruit yields provided additional income (over the income obtained just by selling fruits from the orchard) to the farm family. Net returns as well as B:C ratio were higher when bajra was intercropped either with *Eureka lemon* (Rs.92,595/ha) or Kinnow (Rs.79,279/ha) as compared to maize intercropping. Lowest net returns were recorded when Kinnow was taken as sole crop and lowest B:C ratio seen in maize when raised as pure stand. The local fodder trees also showed tremendous resilience by giving green fodder in harsh summer months during which the rains were more or less scanty in the dryland areas. Therefore, the farmers could get regular income through sale of crops, fire wood as well as fruits. Similar benefits of intercropping in fruit trees which provided additional income to the small and marginal farmers were also reported earlier (Kumar *et al*., 2019; Gupta *et al*., 2020, 2022).

Conclusion

The fodder and field crops raised as intercrops in the fruit trees enhanced growth of citrus along with maize and bajra as intercrops, which provided both green and dry fodders along with grain for human consumption, thus providing extra income to the farmer from the same unit of land. Net returns as well as B:C ratio were higher when bajra was intercropped either with Lemon or Kinnow as compared to maize intercropping. Both size and weight of Kinnow and lemon fruits were higher when intercrops were taken as compared to sole fruit trees. Higher fruit TSS and other quality parameters under intercropping treatments were well related to maximum nutrient uptake under intercropping. The multipurpose trees on the border areas of the farm land helped to save land and increased the cropping area.

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