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Hortipastoral based land use systems for enhancing productivity of degraded lands under rain fed and partially irrigated conditions

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Abstract

Hortipastoral based land-use systems were developed for sub-tropical degraded lands in the central India under rain fed and partially irrigated conditions through long term trials (1991-98) at the Indian Grassland and Fodder Research Institute, Jhansi (India). Under rain fed condition, jujube (*Ziziphus mauritiana* Lamk.) based hortipastoral system, incorporating perennial rain fed fodder grass - buffel (*Cenchrus ciliaris* L.) and legume - stylo (*Stylosanthes hamata* (L.) Taub.), was developed to optimize productivity of the system. Major products of the system were fodder and fruits. The combination of buffel and stylo as mix crop when intercropped with jujube trees gave higher fodder production (4.63 DM t ha^{-1}) than buffel (3.62 DM t ha^{-1}) and stylo (3.26 DM t ha^{-1}) when intercropped separately with jujube trees. Growth and production of fruit trees (5.98 and 5.88 t ha^{-1} average fruit production in the 5th and 6th years respectively) were not affected significantly with various tree-pasture combinations as compared to control (trees alone). Among all treatment combinations, the system gave maximum productivity when buffel and stylo were intercropped with jujube trees as mix crop. Under partially irrigated (drip irrigation) condition, productivity of natural sehima (*Sehima nervosum* (Rottl.) Stapf.) pasture was enhanced from 4.01 to 4.50 DM t ha^{-1} by introduction of fruit trees (Kinnow mandarin, *Citrus nobilis* Lour x *C. deliciosa* Tenora) and stylo. Maximum Kinnow production (6.91 t ha^{-1}) was obtained in the 4th year. Maximum system productivity was obtained when both Kinnow and stylo were introduced in the natural sehima system. There was no adverse effect of tree and fodder components on each other in the long run. Hortipastoral systems offer viable alternatives to the present land uses on degraded lands of central India.

Key word: Central India, forage production, sub-tropical fruits

Introduction

Vast area in India (about 157 m ha) is classified under various types of degraded land where one or more limiting factor(s) render the cultivation of crops economically unviable. As an outcome of untiring efforts of pioneer workers in the field, fruit tree based land use systems have been accepted as an alternative land use option for degraded lands in India (Pareek and Chadha, 1993; Pathak, 1993 and 1999; Pathak and Pathak, 2000 and Saroj *et al.*, 1994). Hortipastoral system is a promising land use system in which fruit trees are grown in association with fodder crops in which there exists, both ecological and economic interactions among different components. Among various fruit trees suggested for hortipastoral systems under rain fed condition, jujube (*Ziziphus mauritiana* Lamk.) is a preferred species because of hardiness and its ability for profitable production under harsh edaphic and climatic conditions, and limited external resources (Sharma and Saran, 1999). While under partially irrigated conditions, cultivation of Kinnow mandarin (*Citrus nobilis* Lour x *C. deliciosa* Tenora), has become popular because of its adaptability to different agro-climatic conditions, heavy bearing potential, reasonable shelf life, and excellent juice quality (Chopra and Joshi, 1971; Jawanda, 1976; Jawanda and Bhambota, 1979, Jawanda and Singh, 1973; and Jawanda *et al*., 1972).

Natural grasslands are main source of fodder to about 500 million animals in India (Swaminathan, 1989) mainly because the area under fodder production is low (4.4% of total cultivated area). According to the latest census (GOI, 1998), the area under fodder crop (6.186 Ha) has further reduced to 3.5% of total cultivable area in India. Most degraded lands falls in the areas of acute fodder shortage. The introduction of pasture component in the fruit tree based land use systems (hortipastoral systems) makes them more attractive to farmers. Buffel (*Cenchrus ciliaris* L.) and sehima (*Sehima nervosum* Rottl. Stapf) are popular pasture grass species. Sehima is highly palatable at all stages of growth, quite nutritious and gives high yield in a well managed natural grasslands (Kanodia *et al*., 1993). Stylo (*Stylosanthes hamata* (L.) Taub.) is a perennial,

rain fed pasture legume species. Introduction of stylo in natural grasses is a common practice to enhance the pasture production and nutritional quality of the fodder (Rai and Pathak, 1985). Therefore, this study was aimed at optimizing the productivity of hortipastoral systems under rain fed and partially irrigated degraded lands in central India.

Materials and methods

Area description

Central Research Farm, Indian Grassland and Fodder Research Institute, Jhansi (78^0 27' E Longitude and 25^0 27' N Latitude, about 275 m above msl) falls under semi-arid region with average rainfall of 850 mm. Soil of the experiment site under rain fed condition was sandy-clay with neutral reaction (pH 6.74 and Electrical Conductivity, EC, 0.025 dm s^{-1}), low in organic carbon (0.184%) and available nitrogen (149.69 kg/ha) and medium in available potassium (152 kg/ha). While the soil of the experiment site under partial irrigation was sandy-clay-loam, neutral in reaction (pH 6.62) and low in EC (0.01 dm s^{-1}), with low organic carbon (0.28 %) and available nitrogen (172.9 kg/ha). Available potassium was in normal range (112 kg/ha).

Treatment and experimental Layout. Four jujube (*Ziziphus mauritiana* Lamk.) cv. Gola plants per treatment combination were planted at 6x6 m spacing in April 1991 in the relevant treatment combinations. Total experimental area was 36x120 m. Fruit trees and pasture components were planted in the following seven treatment combinations, *viz.*, (i) Jujube alone (T1, control); (ii) Jujube+Buffel (T2); (iii) Jujube+Stylo (T3); (iv) Jujube+Buffel+Stylo (T4); (v) Buffel sole (T5); (vi) Stylo sole (T6); and (vii) Buffel+Stylo (T7). Treatment combination number T5, T6 and T7 were raised without jujube trees.

The field of natural pasture of sehima (*Sehima nervosum* (Rottl.) Stapf.) was divided into 12 plots of 18x18 m each. Total experimental area was 48x120 m. Nine Kinnow (*Citrus nobilis* Lour x *C. deliciosa* Tenora) saplings were planted per treatment combination in July 1992 in the relevant treatment combinations at a spacing of 6x6 m. The following four treatment combinations, *viz.*, (i) Natural Sehima pasture (T1, control); (ii) Kinnow alone (without Sehima/stylo) (T2); (iii) Sehima+Kinnow (T3); and (iv) Sehima+Kinnow+Stylo (T4) constituted the experiment.

Establishment and management of trials. Jujube scion were patched budded *in situ* on three months old seedlings of *jharber* (*Z. nummularia* (Burm. F.) Wight and Arn.). The inter-space among jujube trees was utilized for the cultivation of buffel grass (*Cenchrus ciliaris* L.) and stylo legume (*Stylosanthes hamata* (L.) Taub.). Rooted slips of buffel grass were transplanted at a spacing of 50 cm in lines, and lines being 1 m apart. All plants were maintained under rain fed condition. Saplings of Kinnow mandarin were raised on Jatti Khatti (*Citrus Jambheri*) rootstock. All Kinnow plants were irrigated through drip irrigation system. For the maintenance of fruit trees, standard orchard management practices were followed for the application of fertilizers, irrigation (Kinnow only) plant protection chemicals, training and pruning, and other operations. All pasture plots were applied with nitrogen (N) at the rate of 40 kg N ha^{-1} $annum^{-1}$. Boiling water treated seeds of stylo were broadcasted in respective treatment combinations.

Data collection and analysis

Growth (plant height and collar diameter) and yield data were recorded annually for fruits and fodder crops (on dry matter basis). Harvest method was adapted for recording plant biomass of pasture (Odum, 1960). Entire plot was harvested and weighed in the field itself for fresh weight. Samples of 100 g pasture were oven dried for dry matter content. A randomised blockd design was adopted for statistical analysis of data using standard procedure.

Results and discussion

Rain fed condition

Fruit production

Jujube plants showed a steady growth with age in terms of plant height and collar diameter. The plant height varied from 0.87 to 0.92 m in the 1st year (1991). The variation in the 5th year (1995) was 3.14 to 3.54 m (Fig. 1). The collar diameter had variation of 0.87 to 1.01 cm in the 1st year (1991). The variation was raised to 7.69 to 8.48 cm in the 5th year (Fig. 2). During first five years, the plant growth was not affected significantly by cultivation of fodder crops. Trees started yielding fruits from 3rd year onward (1993, 0.125 to 0.164 t ha^{-1} under various treatment combinations having fruit component). There was a steady growth in fruit yield during experimental period, except in 1997 (2.57 to 2.86 t ha^{-1}) due to bad weather. In 1997, the total rainfall (827.9 mm) and number of rainy days (47 days) were less than the preceding year (850.4mm and 52 days, respectively) and the following year (986.4 mm and 52 days, respectively). Unfavourable weather conditions resulted in a severe fruit drop, and the quality of fruits was inferior due to attack of powdery mildew and fruit borer. The yield was raised to 5.37 to 6.55 t ha^{-1} in the 8th year (1998) (Fig. 3). The fruit yield was not affected significantly by growing intercrops in the inter-space. Similar trends of production were obtained by other workers. Raturi and Hiwale (1993) obtained fruit yield of 1.61 and 4.9 t ha^{-1} in the 1st and 3rd years respectively on Horti-silvi-pasture system at Godhra (Gujarat, India). Singh and Osman (1995) harvested 919 kg fruit ha^{-1} under jujube based Hortipastoral system at Hyderabad.

Pasture production. In the first year, the fodder production was low in all treatment combinations, *e.g.*, buffel (1.71 DM t

Table 1. Fodder production of buffel and stylo (DM t ha^{-1}) as influenced by jujube trees

Year (Age)	Buffel		Stylo		Buffel+Stylo		CD at 5%
	Without jujube	With jujube	Without jujube	With jujube	Without jujube	With jujube	
1991 (1)	1.71	1.39	1.86	1.35	2.22	2.82	NS
1992 (2)	0.64	1.15	4.50	5.32	7.83	7.10	NS
1993 (3)	3.03	4.30	4.31	4.21	5.17	5.14	NS
1994 (4)	4.59	4.17	3.23	2.34	4.27	4.77	0.47
1995 (5)	4.53	6.08	4.36	4.32	3.34	4.67	NS
1996 (6)	3.50	4.80	3.61	3.22	3.08	4.20	NS
1997 (7)	2.46	3.46	2.86	2.06	2.81	3.68	NS
Average	2.92	3.62	3.53	3.26	4.10	4.63	

Table 2. Pasture production (DM t ha^{-1}) of Sehima dominated natural pasture under various treatment combinations

Treatment combinations → Age of the system (Year)	Sehima dominated natural pasture (Control)	Sehima + Kinnow	Sehima + Kinnow + Stylo	C. D. at 5%
1 (1993)	2.87	3.18	2.09	NS
2 (1994)	5.87	5.15	5.74	0.70
3 (1995)	4.95	6.12	7.38	NS
4 (1996)	4.02	3.78	3.63	NS
5 (1997)	2.83	2.75	3.95	NS
6 (1998)	3.51	3.14	4.19	NS
Average	4.01	4.02	4.50	

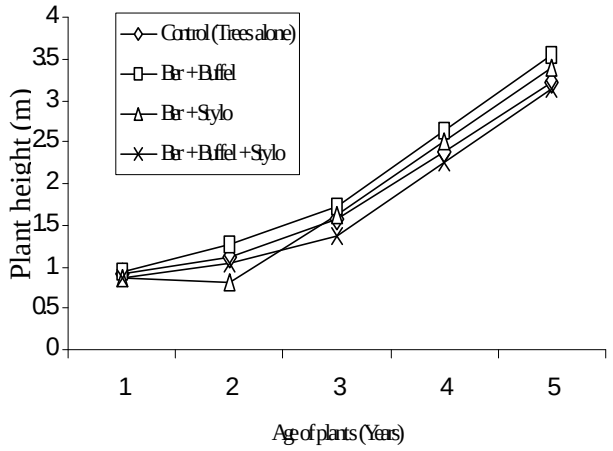

Figure 1. Growth (plant height) of jujube trees under various pasture combinations

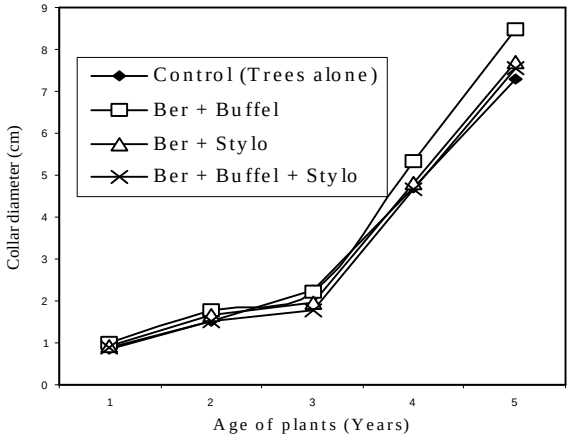

Figure 2. Growth (coller diameter) of jujube trees under various pasture combinations

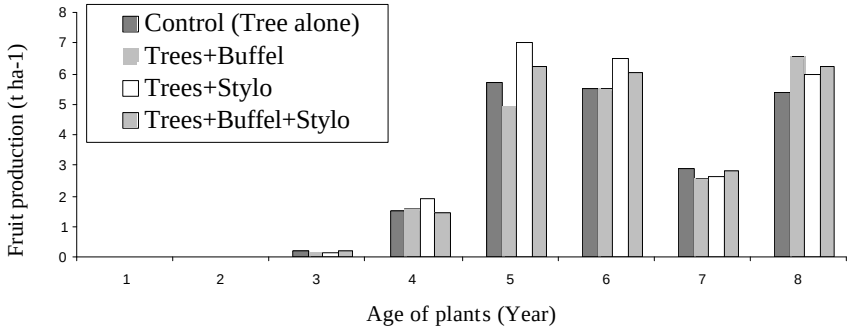

Figure 3. Production of jujube fruit under various pasture combinations

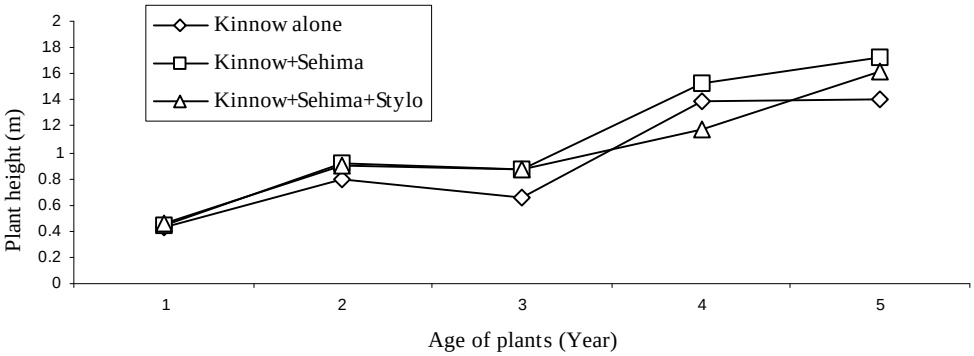

Figure 4. Growth (plant height) of Kinnow plants under various pasture combinations

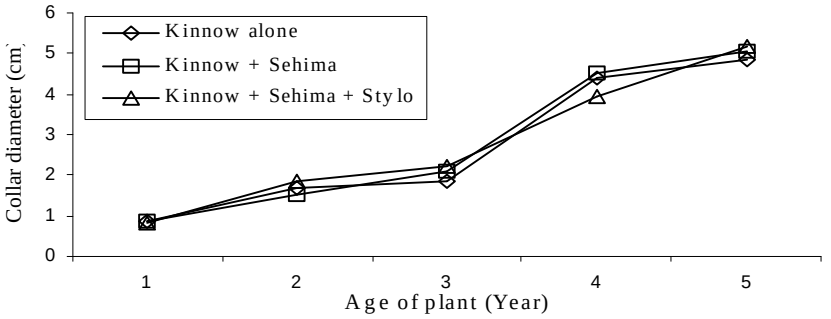

Figure 5. Growth (collar diameter) of Kinnow plants under various pasture combinations

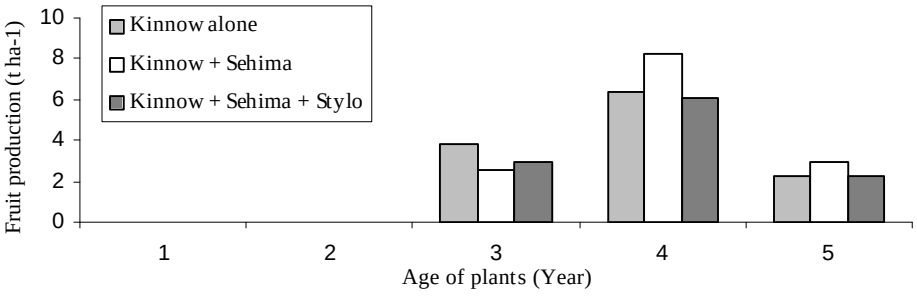

Figure. 6 Production of Kinnow fruits under various pasture combinations

ha^{-1}), stylo (1.86 DM t ha^{-1}) and mixture crop of buffel+stylo (2.22 DM t ha^{-1}). Pasture production showed a general trend of increase in dry matter yield up to 4th-5th year (1994-95). In 1994, the fodder production was 4.59, 3.23 and 4.27 DM t ha^{-1} in buffel, stylo and mixed pasture respectively. It remained constant for the next year, and thereafter started declining (Table 1). Over the period of time, the number of other grass species increased. Among various treatment combinations, the maximum fodder production was obtained when buffel and stylo were grown together as mix crop, except in the 5th (1995) and 6th (1996) years. However, the differences were not significant among various treatment combinations, except in the 4th (1994) year when the jujube trees affected the production of stylo and mix crop of buffel and stylo significantly. Average fodder production of stylo was lower when grown with jujube, however, by and large the production of buffel and mix crop was more when grown with jujube. In spite of loss of area due to trees, the production of fodder with or without trees did not vary significantly, except in the 4th year (1994). The probable reason may be that fertilizers applied to jujube trees were also utilized by the fodder component, for there was no physical barrier between root systems of trees and pasture and thus, better availability of nutrients compensated for the lost area. Raturi and Hiwale (1993) harvested green fodder of 5.5 and 3.89 t ha^{-1} of buffel and stylo respectively in jujube orchard. Similar results were observed by Singh and Osman (1995). They obtained production of 5.98 DM t ha^{-1} stylo and 6.77 DM t ha^{-1} of buffel in custard apple.

Under partial irrigation

Fruit production. Kinnow plants showed a steady growth in terms of plant height and collar diameter during first five years (Fig. 4 and 5). The initial tree height ranged between 0.43 to 0.46 m under various treatment combinations. The variation in plant height in the 5th year ranged between 1.40 to 1.62 m. Collar diameter ranged between 0.81 to 0.86 cm in the 1st year, and between 4.83 to 5.16 cm in the 5th year. During the initial years some Kinnow plants were replaced due to mortality. The replaced plants reduced the average plant growth. This may be the probable reason for slower plant growth during initial years and then sudden growth by the end of 3rd year. Thereafter, the increase in the tree growth was marginal. Kinnow started producing fruits from the 3rd year (1995) onward. The fruit production was nominal (2.56 to 3.86 tha^{-1}) in the first year, which increased to 6.42-8.21 t ha^{-1} in 4th year. The fruit production decreased in the 5th year (ranging between 2.26 to 2.90 t ha^{-1}), mainly due to alternate bearing character of the tree. The fruit production reduced to 2.26 to 2.90 t ha^{-1} in the 5th year, mainly due to alternate bearing character of the tree (Fig. 6). Fruit production was damaged considerably in the sixth year due to severe attack by fruit sucking moth.

Pasture production

Pasture production was low in the first year, 1993 (2.09 to 3.18 DM t ha^{-1}). There was continuous increase in pasture production in first three years. It ranged between 4.95 to 7.38 DM t ha^{-1} in the third year (1995). Thereafter, there was a decline in pasture production in all treatment combinations. It varied from to 3.14 to 4.19 Dm t ha^{-1} in the sixth year (1998) (Table 2).

Land degradation is an environment and social menace. Hortipastoral systems have a great potential for assuring conservation and land sustainability for degraded lands. The socio-environmental challenges of areas falling under degraded lands. Such as rapid increase in human and cattle population, decreasing land-man ratio, widespread deforestation, excessive grazing, soil erosion, environmental deterioration, etc., can be encountered by encouraging hortipastoral systems for different agro-climatic niches.

Conclusion

Based on a long-term trial, it has been established that jujube trees when grown with buffel and stylo as intercrops, gave maximum system productivity when compared with other combinations. Kinnow based sehima dominated Hortipastoral system gave maximum productivity when tree, grass and legume components were grown together. There was no significant adverse effect of tree and pasture on each other in the long run. Hortipastoral systems have much to offer in checking land degradation trend and in providing much needed products, like, fruit, fodder, fuel wood, etc. Hortipastoral systems being site specific in nature, need to be developed according to the location and people's requirements. They are also governed by the extent of resources at the disposal of an individual farmer. Therefore, emphasis should be there on developing a few generic technologies and leaving ample scope for the individual farmers to innovate.

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