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Yield and quality assessment of annual and perennial fodder intercrops in *Leucaena* alley farming system

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Abstract
The introduction of leguminous trees in agroforestry and livestock feeding systems offers promise for bridging the huge demand and supply gap in animal feed and fodder in India. *Leucaena,* a miracle tree for its fast growth, multipurpose uses, nitrogen fixing ability, etc. finds its value in agroforestry system. In the present study, the fodder crop productivity in the *Leucaena* (Subabul) alleys was not affected and the above ground biomass of the system was more when compared to sole fodder production of annual (maize + cowpea followed by berseem + ryegrass) and perennial Napier Bajra hybrid. The fodder productivity of perennial and annual crops was 140.2 and 110.3 t/ha in *Leucaena* alleys against the 128.7 and 98.7 t/ha in open, respectively. The *Leucaena* based silvi-pastoral model was found highly productive, which yielded fuelwood (3.52 t/ha on dry weight basis) in addition to fodder from inter-crops and *Leucaena*. Biomass yield of one hectare of inter-cropping was found equivalent to 1.45 ha by sole fodder crops. Moreover, the Subabul based fodder inter-cropping produced 15 per cent higher protein than the sole fodder crop on unit area basis.

Keywords: Alley farming, Fodder crops, *Leucaena*, Productivity, Quality, Silvi-pastoral system

Introduction

Developing countries are experiencing great pressure to increase food production for the rapidly increasing human population. The food pressure on land is so acute that there is little scope for extending the area under forage crops for increasing livestock population. Therefore, crop intensification either in space (intercropping) or in time (sequential cropping) or both is only feasible option to meet the growing demand. Interest has grown in the development of high producing land use technologies involving intercropping of woody (particularly leguminous) species with food or forage crops in an agroforestry system. One such technology is alley farming for food and animal production, where the increase in production has come largely from improvement in productivity rather than from expansion of cultivated land.

Despite the potential benefits that can be derived from fodder based contour hedge row system on sloping lands (Benge, 1987), their use on flat fertile lands never gained popular acceptance among the farmers due to huge demand for food crops. Among the different tree species, *Leucaena* has emerged as a model tree for alley farming due to its fast growth, N_2 fixing ability, nutritious fodder, adaptability on diverse conditions, high coppicing ability etc. In alley farming, the hedgerow trees are kept pruned during the cropping period to minimize shading of the accompanying crops and favour crop productivity (Kang *et al.*, 1985 and 1990). *Leucaena* based alley cropping has extensively been reviewed on slopping land for food/ fodder production but no information is available on performance of *Leucaena* based alley farming in irrigated agro-ecosystem. Therefore, the present study was planned to access *Leucaena* based alley farming under irrigated condition.

Materials and Methods

The present field study was carried out in Punjab Agricultural University, Ludhiana. Three diverse *Leucaena* sources *viz*., K-8 (*Leucaena leucocephala)*, K-156 (*Leucaena diversifolia*) and K-743A (*L. leucocephala x L. diversifolia*) selected on the basis of their diverse mimosine content were raised in randomized block design at the spacing of 4 x 2 m in four replications. The fodder crops *viz*., napier bajra hybrid (PBN-233, perennial), maize (J-1006) + cowpea (Cowpea-88) followed by berseem (BL-10) + ryegrass (Ryegrass No.1) were grown in between the rows of four years old *Leucaena* plants in their respective seasons each in two replications of three *Leucaena* sources. The recommended package of practices of Punjab Agriculture

University were followed for the growing of fodder crops. Three harvest of *Leucaena* plants were taken during the month of April, August and December. The grasses were also harvested at their optimum maturity stage *i.e.*, maize + cowpea (one harvest), rye grass + berseem (four harvests) and napier bajra hybrid (three harvests). Green biomass was recorded in the field itself. Whereas, the oven dry biomass at 70 ± 1°C was recorded in the laboratory. Quadrate method (1 m^2) was followed to record the biomass and three quadrates per crop per replication were harvested to finally compute it on hectare basis.

The nutritional analysis for proteins, carbohydrates, total ash, mimosine and tannins from dried powder pure *Leucaena* leaves and mixed with inter-cultivated fodder crops in the ratio of 1:1, 1:2 and 1:3 was done as per the standard procedures. Crude protein, tannins and ash content were estimated as per the procedure of AOAC (1970); carbohydrates by following Dubois *et al.* (1986) and mimosine by rapid calorimetric method of Mastsumoto and Sherman (1951). The data on different parameters were analyzed following standard procedure (Gomez and Gomez, 1984).

Results and Discussion

The *Leucaena* blocks were divided into two parts, annual (maize + cowpea followed by berseem + ryegrass) and perennial (napier bajra hybrid) type intercropping depending upon nature of the fodder crop.

Leucaena yield

The data in table 1 shows that K-8 source produced the maximum green leaf biomass (3.74 kg/plant per harvest), which was significantly higher than K-156 (2.6 kg/plant)

Table 1. *Leucaena* green and dry biomas

Leucaena	Leaf biomass (kg/plant)				Shoot biomass (kg/plant)				Leaf: shoot ratio			
source	Apr.	Aug.	Dec.	Mean	Apr.	Aug.	Dec.	Mean	Apr.	Aug.	Dec.	Mean
K-8	5.00	4.10	2.13	3.74	3.05	4.75	1.98	3.26	1.64	0.86	1.11	1.15
	(1.55)	(1.45)	(0.73)	(1.24)	(1.06)	(1.72)	(0.72)	(1.17)	(1.48)	(0.84)	(1.02)	(1.06)
K-156	3.13	3.30	1.58	2.67	1.78	3.83	1.49	2.37	1.76	0.76	1.08	1.13
	(1.11)	(1.18)	(0.54)	(0.94)	(0.62)	(1.37)	(0.53)	(0.84)	(1.78)	(0.86)	(1.00)	(1.12)
K-743A	2.98	3.10	1.32	2.46	1.67	3.72	1.35	2.25	1.84	0.82	0.97	1.09
	(1.01)	(1.09)	(0.46)	(0.86)	(0.59)	(1.35)	(0.48)	(0.81)	(1.73)	(0.81)	(0.96)	(1.06)
Mean	3.70	3.50	1.67	2.95	2.16	4.10	1.60	2.62	1.71	0.85	1.05	1.13
	(1.22)	(1.24)	(0.58)	(1.01)	(0.76)	(1.48)	(0.58)	(0.94)	(1.61)	(0.84)	(0.99)	(1.07)

* Figures in parentheses depict the dry biomass

C.D. at 5% level	Leaf biomass	Shoot biomass	Leaf: shoot ratio
Leucaena source	0.31 (0.07)	0.29 (NS)	NS (NS)
Harvest	0.31 (0.07)	0.29 (0.10)	0.20 (0.18)
Leucaena source x harvest	NS (NS)	NS (NS)	NS (NS)

Table 2. Quality parameters of different *Leucaena* sources at variable harvesting stages

Leucaena	Crude protein (%)				Carbohydrate (%)				Ash (%)			
Source	Apr.	Aug.	Dec.	Mean	Apr.	Aug.	Dec.	Mean	Apr.	Aug.	Dec.	Mean
K-8	22.00	22.85	27.30	24.05	13.40	7.80	16.31	12.50	7.40	9.22	7.8	8.14
K-156	24.20	23.26	29.40	25.20	11.92	7.70	18.42	12.68	7.42	9.19	7.3	7.97
K-743A	21.20	25.00	27.50	24.20	14.12	8.20	22.00	14.77	7.16	9.23	7.6	7.99
Mean	22.40	23.70	28.06	-	13.14	7.90	18.91	-	7.32	9.21	7.6	-

Leucaena	Mimosine (%)				Tannins (%)			
Source	Apr.	Aug.	Dec.	Mean	Apr.	Aug.	Dec.	Mean
K-8	1.60	2.10	3.20	2.30	2.77	3.70	4.80	3.76
K-156	1.18	1.64	2.80	1.87	3.20	3.30	4.10	3.53
K-743A	0.80	1.20	2.20	1.40	2.60	2.90	4.40	3.35
Mean	1.19	1.64	2.73	-	2.85	3.30	4.43	-

C.D. at 5% level	Crude protein	Carbohydrate	Ash	Mimosine	Tannins
Leucaena source	0.09	0.06	0.16	0.04	0.14
Harvest	0.13	0.07	0.19	0.04	0.15
Leucaena source x harvest	0.16	0.11	0.20	0.06	0.24

and K-743A (2.46 kg/plant). These values calculated on hectare basis reflects 14.02, 9.75 and 9.22 t green leaves/ha, respectively for above mentioned sources. The superior performance of K-8 in terms of biomass in comparison to other sources has also been reported by various workers in different parts of the country (Nerkar 1984 and Relwani *et al*., 1985). The harvesting in the month of August recorded the maximum dry leaf biomass of 1.24 kg/plant, which was significantly higher than December harvest of 0.58 kg/plant but at par with April harvest (1.22 kg/plant). The higher biomass during monsoon season was due to favourable growth conditions than other two harvests. The non-edible dry biomass also recorded the similar trend. The K-8 yielded 4.39 t/ha of dry leaf biomass, which was significantly more than K-156 (3.15 t/ha) and K-743A (3.04 t/ha). Irrespective of *Leucaena* sources, 2.82 kg/plant dry fuelwood was obtained, which is equivalent to 3.5 t/ha in addition to the leaf biomass. The time of harvesting has significant effect on the edible: non-edible biomass ratio (Table 1). Harvesting in the month of April was significantly superior in terms of fodder component (1.71) than other two harvests *i.e.*, August (0.85) and December (1.05). The ratio more than one indicates the higher proportion of edible part than the non-edible portion. The leaf and shoot biomass during the monsoon harvesting was highest, still the leaf: shoot ratio during August harvesting was less than one, which indicated proportionally higher woody biomass production during April to August months than December to April or August to December.

The time of harvest as well as inter-source variation in *Leucaena* leaf biochemical content was also significant. The inter-source differences as recorded during the present investigation are in accordance to those reported by Kaur *et al.* (2001). The value of protein, mimosine and tannin content were found positively correlated among themselves, whereas, ash and carbohydrate content were negatively related with other parameters (Table 2). The carbohydrate and ash content also had negative relationship among themselves; maximum values for carbohydrate and minimum for ash content were recorded during monsoon harvest. In general, carbohydrates were comparatively less during monsoon season than summer/winter season, whereas, mimosine content in leaves increased with time from April to December. New leaves had higher mimosine than the older ones and the concentration is related to growth rates (better growth with higher mimosine). The effects of season/time of year on fluctuations in mimosine concentration have also been observed by Gupta *et al.* (1992). The anti-quality parameters mimosine and tannins were minimum in K-743A followed by K-156 and K-8. The variation in quality and anti-quality factors as observed in present studies are in accordance to many other studies (Tangendjaja *et al.,* 1986; Faria Marmol, 1994).

Fodder yield

The intercrop fodder yield was least affected by the *Leucaena* plants (Table 3). The maize + cowpea yield though varied non-significantly in alley and open condition

Table 3. Fodder crop yield* under *Leucaena* based silvi-pastoral model

Leucaena source	Maize+cowpea green (dry) yield (t/ha)	Ryegrass + berseem green (dry) yield (t/ha)					Napier bajra hybrid green (dry) yield (t/ha)			
		C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	Mean
K-8	29.5	18.3	21.9	21.0	17.6	19.7	36.25	43.75	57.50	45.70
	(5.0)	(1.7)	(2.4)	(2.5)	(2.3)	(2.2)	(5.50)	(8.00)	(11.75)	(8.50)
K-156	27.8	17.5	21.5	14.7	14.8	17.1	32.50	40.00	55.00	42.50
	(4.9)	(1.6)	(2.3)	(1.7)	(1.9)	(1.9)	(4.75)	(7.25)	(11.25)	(7.75)
K-743A	27.5	17.0	19.9	14.6	14.3	16.4	31.25	38.75	52.50	40.75
	(4.6)	(1.5)	(1.6)	(1.6)	(1.9)	(1.6)	(4.50)	(7.00)	(10.75)	(7.50)
Control	25.5	22.0	21.5	14.2	15.5	18.3	32.50	41.25	55.00	42.75
	(4.9)	(2.2)	(2.3)	(1.6)	(2.2)	(2.1)	(5.50)	(6.50)	(9.25)	(7.00)
Mean	28.5	18.7	21.2	16.1	15.5	17.7	33.00	40.75	55.00	42.98
	(4.8)	(1.7)	(2.1)	(1.8)	(2.1)	(1.9)	(5.00)	(7.25)	(10.75)	(7.92)

*figures in parenthesis depict dry biomass

C.D. at 5% level	Maize + cowpea green (dry) yield	Ryegrass + berseem green (dry) yield	Napier bajra hybrid green (dry) yield
Leucaena source		1.60 (3.0)	NS
Harvest		1.60 (NS)	4.90 (1.80)
Leucaena source x harvest	N.S. (NS)	3.20 (NS)	NS (NS)

Table 4. *Leucaena*: ryegrass + berseem ratio and nutritional value

Leucaena	**Crude protein (%)**				**Carbohydrate (%)**				**Ash (%)**				**Mimosine (%)**				**Tannins (%)**			
Source	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**
K-8	20.63	20.08	19.81	20.17	5.70	2.85	1.42	3.32	9.07	9.38	9.53	9.32	1.16	0.55	0.38	0.69	1.80	0.90	0.40	1.03
K-156	21.50	20.60	20.25	20.78	5.96	2.98	1.47	3.47	8.98	9.32	9.49	9.26	0.90	0.44	0.27	0.53	2.20	1.10	0.50	1.26
K-743A	20.92	20.28	20.29	20.49	6.06	3.03	1.51	3.53	8.99	9.32	9.50	9.27	0.70	0.33	0.19	0.40	1.60	0.80	0.30	0.90
Mean	21.01	20.32	20.11		5.90	2.95	1.47		9.01	9.34	9.50		0.91	0.44	0.28		1.86	0.93	0.40	

C.D. at 5% level	**Crude protein**	**Carbohydrate**	**Ash**	**Mimosine**	**Tannins**
Leucaena source	0.25	0.06	0.08	0.04	0.08
Harvest	0.24	0.07	N. S.	0.04	0.06
Leucaena source x harvest	N. S.	0.10	N.S.	0.06	0.13

but the yield was more in alleys. Comparatively more succulence was observed in maize + cowpea when grown in *Leucaena* alleys than in open (83.04 and 80.78 per cent moisture content, respectively). The higher yield in hedgerows is due to better penetration of solar radiation with regular lopping and nitrogen fixation ability of *Leucaena*.

The *Leucaena* inter-source differences on ryegrass + berseem yield were significant. The average maximum fodder production of 19.7 t/ha per harvest was in K-8 alley, which was significantly superior to K-156 and K-743A (17.1 and 16.4 t/ha, respectively) but at par with yield under control 18.3 t/ha (grown in open). Total dry biomass of 7.7 t/ha reflects 89.6 per cent moisture and 10.4 per cent roughage in the fodder in *Leucaena* based silvi-pastoral model (Table 3). In total, the crop yield under K-8, K-156 and K-743A was recorded to be 78.8, 68.5, 65.8 t/ha in *Leucaena* rows and 73.2 t in open (Table 5). The different harvests also had significantly variable fodder yield. The data pertaining to napier bajra hybrid biomass depicted per cut average green matter yield of 43.0 t/ha, which was equal to the control value of 42.75 t/ha. The total annual napier yield (t/ha) in *Leucaena* alleys was estimated to be 137.5 (K-8), 127.5 (K-156), 122.5 (K-743A), which was at par to the yield in open (128.7). The results revealed that the intercropping of *Leucaena* and napier had positive interaction. Similarly higher yields of napier grass has been reptored earlier by Mureithi *et al.* (1995).

The interaction in *Leucaena* based silvi-pastoral system on growth and/or development was not found competitive rather facilitatory. Regular harvesting of *Leucaena* plants as well as the leguminous crop mixture in the annuals (cowpea with maize and berseem with ryegrass) showed stable interaction rather than negative tree-crop interaction. Saharan *et al.* (1989) also reported the positive association of *Leucaena* with forage crops like hybrid napier, lucerne, oat and other cereal forages. However, Meena (2011) reported considerable reduction in yield of associated crops than sole cultivation but losses can be compensated by additional yield and quality obtained from *Leucaena* biomass.

Leucaena supplemented feed quality

Foliage of *Leucaena* is highly palatable, nutritious and relished by cattle, goat and wildlife but it cannot be used as sole feed because of presence of non-protein amino acid, mimosine [â{N-3hydroxy-4(H) pyridone} amino propionic acid]. Thus, *Leucaena* leaves were mixed with inter-cultivated forage crops for supplemented feed quality evaluation. Protein and mimosine are two important components among the studied parameters in the feed. The nutritive values of pure *Leucaena* sources presented in table 2, indicated that the anti-quality bio-chemicals (mimosine and tannins) were comparatively less in K-743A than K-156 and K-8, whereas, other important biochemical, crude protein exhibited reverse trend.

The data on qualitative parameters of *Leucaena* mixed with ryegrass + berseem, in different proportion have been presented in table 4 and similar results were obtained with other two combination. The differences in values with respect to different *Leucaena* sources, the proportion of mixing and their interaction were significant in almost all the parameters. The anti-quality parameters were found in the order of K-743A<K-156<K-8 at all mixture levels. Similar trend of mimosine and tannins in these *Leucaena* sources have been recorded earlier by Norton *et al.* (1995). Irrespective of the *Leucaena* source, the value of protein, carbohydrate, mimosine and tannins decreased, while the ash content increased with the increase in proportion of inter-cultivated fodders. The reduction in the carbohydrate, mimosine and tannin content was drastic (70-76%) but slight in protein (4 to 16%) when the proportion of forage crops in *Leucaena* was increased from 1:1 to 1:3 ratio. Kaur and Gupta (2003) observed very low concentration of mimosine and tannins in blended fodders of berseem + shaftal: subabul foliage in the ratio of 40:60 and 60:40, which were quite below the toxic level. The level of protein and carbohydrates in blended fodder were also found to be in accordance with the recommended standards. The feeding of *Leucaena* with other forages to minimize the anti-quality factors also find the support of Devendra (1982), where 50 per cent amount of *Leucaena* forage in diet has been recommended, whereas, Norton (1994) emphasized 30-50 per cent of *Leucaena* in the diet for optimum performance of cattle, sheep and goats.

System productivity

The *Leucaena* based silvi-pastoral model was found highly productive (Table 5). Growing of annual crops [maize + cowpea (summer) – berseem + rye grass (winter)] and perennial crop (napier bajra hybrid) produced 98.7 and 128.7 tones green biomass per hectare, whereas, when grown in *Leucaena* alleys the total fresh edible biomass was estimated to be 110.3 t/ha and 140.2 t/ha, respectively. On dry weight basis, these figures were equivalent to 16.3 t/ha and 27.4 t/ha, with the additional shoot biomass (fuel wood) increasing the figure on fresh weight basis to 120 t/ha and 150 t/ha and dry weight basis to 19.8 t/ha and 30.9 t/ha, respectively (Table 5). The productivity of the system, however, varied with respect to *Leucaena* sources and followed the order of K-8>K-156>K-743A on green as well as dry weight basis. Grewal (1995) recorded 19 t/ha/yr napier grass in addition to 1.9 tones of pruned green foliage in *Leucaena*-napier grass system and recommended that this system for fuel wood and fodder is far superior to raising sole crops under rainfed conditions. Bhatt *et al.* (2006) recorded that *Leucaena*-forage crop based systems had the 1.5 - 2.25 times higher productivity than pure pasture based system. The system maintains higher soil moisture and organic carbon for sustainable biomass production for longer period.

One hectare of *Leucaena* + annual crops produced fodder equivalent to 1.12 ha of sole annual crops, where

Table 5. Biomass production in *Leucaena* based silvi-pastoral model

***Leucaena* source**	**Fresh biomass (t/ha)**				**Dry biomass (t/ha)**			
	Leucaena		**Perennial (napier bajra hybrid)**	**Annual (cowpea- maize + berseem-ryegrass)**	***Leucaena***		**Perennial (napier bajra hybrid)**	**Annual (cowpea-maize + berseem-ryegrass)**
	Leave	**Shoot**			**Leave**	**Shoot**		
K-8	14.025	12.075	137.5	108.3 (29.5+78.8)	4.650	4.387	25.25	13.9 (5.0+8.9)
K-156	9.750	8.850	127.5	96.3 (27.8+68.5)	3.525	3.150	23.25	12.4 (4.9+7.5)
K-743A	9.225	8.437	122.5	93.3 (27.5+65.8)	3.187	3.037	22.25	11.2 (4.6+6.6)
Average	11.00	7.132	129.2	99.3 (28.3+71.0)	3.787	3.525	23.58	12.5 (4.8+7.7)
Control	-	-	128.7	98.7 (25.5+73.2)	-	-	21.25	13.2 (4.9+8.3)

as, the total dry biomass (edible + non-edible) was equivalent to 1.5 ha. Similarly, one ha of *Leucaena* + perennial crop (napier bajra hybrid) produced fodder equivalent to 1.09 ha of sole napier bajra hybrid, whereas, the total dry biomass including fuel wood was equivalent to 1.45ha. In terms of protein supplement, *Leucaena* based silvi-pastoral model produced 55.03 and 33.03 per cent more protein with perennial (napier bajra hybrid) and annual (maize + cowpea followed by berseem + rye grass) fodder crops, respectively than sole fodder crops. It is, therefore, advantageous to grow perennial crop in *Leucaena* alleys than the annual crops to make saving in cost of production. The ratooning of napier bajra hybrid also offers on opportunity of continuous supply of green forage.

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