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Fodder yield potential of cowpea and mahaneem (*Ailanthus excelsa* Roxb.) under Agro-Silviculture system in a Semi-Arid Region of India

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Abstract
Fodder is basic need of livestock industry but due to climate change, deforestation and increasing human population as a result fodder availability decrease day by day in India as well as worldwide. Therefore, an experiment on intercropping of two popular varieties of cowpea under Mahaneem based agri-silviculture systems with different spatial arrangements was conducted to find out the best combination of intercrop with tree crop to reduce the scarcity of fodder in semi-arid and arid region of Haryana, India. The Mahaneem trees were planted at four different spacing configurations (10 × 20 m, 10 × 10 m, 10 × 6.5 m, and 10 × 5 m) in March 2013 at Regional Research Station, Bawal, CCS Haryana Agricultural University, Haryana, India. Two cowpea varieties *i.e.*, Pusa Sukomal and Pusa Dharni were used as intercropop under different spatial arrangement of Mahaneem. Based on two-year study (2020-21 and 2021-22), the data revealed that the maximum *Ailanthus* green fodder yield as well as dry fodder yield was recorded under planting spacing 10 x 5 m whereas, maximum cowpea fodder yield was recorded under *Ailanthus* planting spacing of 10 x 10 m during 2020 - 21 and 2021- 22. The maximum fodder yield per year was maximum recoded 10 x 5 m planting spacing with intercropping cowpea variety Pusa Dharni as compared sole planting of *Ailanthus* tree at various spacing and sole planting of cowpea varieties *i.e.*, Pusa Sukomal and Pusa Dharni during both experimentation year. Hence, 10 x 5 m planting spatial arrangement of Mahaneem with intercropping cowpea variety Pusa Dharni is recommended to the farmers of arid and semi-arid region of Haryana, India for higher green fodder as well as dry fodder yields.

Keywords: Climate change, fodder scarcity, *Ailanthus excelsa*, cowpea and tree spacing configurations

Introduction
In numerous Indian districts, the lack of fodder presents a serious obstacle to the country's livestock and agricultural industries. Green fodder (35.6%), dry fodder (10.5%), and concentrate feed (44%) are currently extremely scarce in the country (Singh *et al*., 2022) [13]. For cattle to be healthy and productive, this is essential to millions of farmers' livelihoods. There must be an adequate supply of nutrient-rich feed. A solution for solving the problem of fodder scarcity in India is plantation of fast-growing fodder purpose trees in agroforestry/ agri-silviculture systems offer an alternative to overcome the challenge of fodder deficiency in India. Intercropping of cowpea under Mahaneem based agri-silviculture system is better opportunity to reduce scarcity of fodder in semi-arid and arid region of India and throughout the world.
The traditional cropping systems of semi-arid and arid regions of Asia, Africa, Central America, and South America, the cowpea (*Vigna unguiculata* L.) play a vital role as a staple food legume (Henriet *et al*., 1997; Mortimore *et al*., 1997; Singh *et al*., 1997a; Van Ek *et al*., 1997) [5, 10, 17, 21]. With average grain yields of 3 q/ha and fodder yields ranging from 25 to 45 t/ha, India is the leading producer of cowpea in Asia, delivering about 0.5 million tonnes from 1.5 million hectares of land. Cowpea is well-known for its nutrient-rich content, making it an invaluable animal feed that improves the overall health, productivity and welfare of livestock. Because of its complete nutritional profile and high protein content, cowpeas are considered to be important ingredients in well-balanced livestock diets, especially for the health of cattle (Singh and Tarawali, 1997) [18].

Singh *et al*. (2020) [19] have reported that in the first stage of pod growth, green cowpea fodder contains 15%–25% crude protein and 50% digestible carbs. A semi-erect group of medium-maturing, dual-purpose varieties has been created by cleverly combining semi-erect varieties, including both early and classic spreading types, to increase output. The yields of these types are excellent; they exceed 1.5 t/ha for grains and 2.5 t/ha for haulms (Singh *et al*., 2003) [16].

Nevertheless, Mahaneem (*Ailanthus excelsa* Roxb.) grows easily, therefore serving as an essential source of fodder in India's dry and semi-arid regions. Mahaneem is a multipurpose tree (MPT) that is widely grown in these harsh conditions. It is especially recognising its ability to give tiny ruminants as a nutritious and high-protein feed (Nair *et al*., 2022) [11]. Many as a crucial element in sustainable development acknowledge Mahaneem, as it considerably enhances the standard lifestyle for farmers with limited resources in semi-arid areas. Its noteworthy qualities, such adaptability, quick development and increased resistance to biotic and abiotic challenges, highlight its significance for sustainable agriculture (Deswal *et al*., 2022) [2]. Notable nutritional components were identified in the Ailanthus (*Ailanthus altissima*) harvested leaves after analysis. According to Ganai *et al*. (2010) [3], the leaves have the following compositions of dry matter contents: 18.22% crude protein, 4.40% ether extract, 15.79% crude fibre, 50.04% nitrogen-free extract, 26.60% neutral detergent fibre, 18.10% acid detergent fibre, 8.50% hemicellulose, 5.11% acid detergent lignin, 11.41% total ash, 1.98% calcium and 0.27% phosphorus. These results highlight the high nutritional content of Ailanthus leaves, establishing them as a useful source of crude protein and a viable substitute for protein in cow diets (Sumathi *et al*., 2017) [20].

The study examined intricate relationships related to meeting the demand for fodder in Haryana's semi-arid climate, with a particular emphasis on cowpea under mahaneem base agri-silvicultural farming. Through an in-depth analysis of the agro-silviculture system, our main goal is to provide insights into sustainable practices that support the region's economic growth. We propose to learn more about the possible sustainability of cowpea production under Mahaneem-based Agro-Silviculture, promoting sustainable agriculture in semi-arid region, by examining the interactions among various factors. It is expected that the results of this study will contribute to the advancement of agricultural science by helping to design sustainable and profitable agricultural systems in similar climatic circumstances around the world.

Materials and Methods

The experimental site is situated at Regional Research Station, Bawal, CCS Haryana Agricultural University, Haryana which geographically located at 28.1°N latitude and 76.5°E longitude with 266 metres above mean sea level. The research was conducted between two consecutive years *i.e.*, 2020-2021 and 2021- 2022. The research site has a climate with hot summers (between 24- 48 °C) and frigid winters (0 to 5 °C) with an average 350-550 mm of rain falling. A randomised block design was use in the experiment, with four treatments that were replicate three times. A nine-year-old Mahaneem (*Ailanthus excelsa*) agroforestry plantation was used to the subject of data collection with the aim to evaluate its performance under four distinct spatial arrangements.

The Mahaneem trees were strategically planted at four different spacing configurations (10 × 20 m, 10 × 10 m, 10 × 6.5 m, and 10 × 5 m) in March 2013. Subsequently, in July, 2020 & 2021, cowpea planted as intercrop under Mahaneem based agro-forestry system and the harvesting of cowpea took place in October, providing valuable fodder crops in both year (2020 and 2021). In October, the trees underwent lopping to facilitate the assessment of green fodder yield. The determination of dry fodder yield involved subjecting one kilogram of green leaf samples to a drying process. On the other hand, the calculation of green leaves from the trees involved a destructive sampling method, which included the comprehensive measurement of the total fresh green leaves' weight through direct weighing of the leaves. After recording of fresh weight, all the samples were oven dried at 65 °C and the oven dry weight was use to determining the dry leaves on a hectare basis. Randomised block design (RBD) methods were use to analyse the experiment's data using statistical analysis (ANOVA) in the MS Excel programme on a computer system. This was done for each of the different characters that were the subject of this experiment. Based on the null hypothesis, the "F" test was used to determine the significance of the treatment differences. In cases where treatment effects were significant, the crucial difference (CD) at the five percent probability level was used to compare the treatment means. The appropriate standard error (S.Em.±) was determined for each case (Panse and Sukhatme, 1967) [12].

Results and Discussion

Fodder Production of *Ailanthus excelsa* under agro-forestry system

The present data revealed that the maximum *Ailanthus* green fodder yield 7.64 & 7.47 t/ha and *Ailanthus* dry fodder yield 25.23 & 24.64 q/ha was recorded under *Ailanthus* planted at 10 × 5 m spacing with intercropping cowpea variety Pusa Dharni among all treatments during 2020 - 21 and 2021- 22 (Table 1). When compare between sole tree plantations at various planting spacing, data depicted table 1 shows that planting spacing 10 x 5 m has maximum green fodder yield (7.50 & 7.13 t/ha, respectively) and dry fodder yield (24.74 & 23.54 q/ha, respectively) during both experimentation year. Although, intercropping of cowpea varieties at various spatial arrangement data shows that maximum fodder yield (7.64 & 7.47 t/ha green, 25.23 & 24.64 q/ha dry) was recorded *Ailanthus* plant at higher density 10 x 5 m and intercropping cowpea variety Pusa Dharni during both years. The fodder production of Mahaneem tree is largely depending on farm lands and canopy management and enough nutrients (Handa *et al*., 2016) [4]. An average *Ailanthus excelsa* tree yields about 5 to 7 quintals of green leaves twice a year (Mann and Sharma, 1995 and Meena *et al.*, 2005) [7, 8]. Kumar *et al.* (2001) [6] also concluded that trees of 12 years can yield up to 400 kg of green fodder annually which can be sold at market for Rs. 100-150 per 100 kg. Meena *et al*. (2003) [9] studied the effect of eight years old Mahaneem (*Ailanthus excelsa*) densities, *i.e*. 25, 50, 75 and 100 trees/ha on performance of fodder crops *viz*., *Cenchrus setigerus* and fodder cowpea in the ratio of 1:1, 1:2 and 2:1. They revealed that the highest green and dry fodder yield were obtained with tree density of 75 trees/ha. Singh *et al*. (2014) [15] also reported that the tree fodder yield was 0.53, 0.20 and 0.07 t/ha from *Colophospermum mopane*, *Prosopis cineraria* and *Ailanthus excelsa* respectively. The production of leaf fodder is 0.8- 1.00 tones per tree in *Ailanthus excelsa* (Singh 2011) [14]. Thus, overall, fodder production of Mahaneem found to be increased with close spacing and age which was higher than sole plantation.

Table 1: Effect of different spatial arrangements on green and dry fodder yield of *Ailanthus Ailanthus excelsa* leaves during 2020-21 and 2021-22

Treatment combinations		*Ailanthus* green fodder weight (t/ha)		*Ailanthus* dry fodder weight (q/ha)	
***Ailanthus* planting spacing (m)**	**Variety of cowpea**	**2020-21**	**2021-22**	**2020-21**	**2021-22**
10 x 20	Sole tree	2.23	2.11	7.37	6.97
10 x 10	Sole tree	4.52	4.27	14.90	14.07
10 x 6.5	Sole tree	5.90	5.60	19.47	18.49
10 x 5	Sole tree	7.50	7.13	24.74	23.54
10 x 20	Pusa Sukomal	2.25	2.20	7.43	7.24
10 x 10	Pusa Sukomal	4.56	4.47	15.03	14.73
10 x 6.5	Pusa Sukomal	5.96	5.80	19.68	19.12
10 x 5	Pusa Sukomal	7.59	7.35	25.03	24.26
10 x 20	Pusa Dharni	2.27	2.21	7.50	7.28
10 x 10	Pusa Dharni	4.60	4.49	15.17	14.81
10 x 6.5	Pusa Dharni	6.02	5.87	19.86	19.35
10 x 5	Pusa Dharni	7.64	7.47	25.23	24.64
CD @ 5%		0.29	0.26	0.96	0.86

Fodder Production of cowpea under agro-forestry system

The green and dry fodder yield of cowpea was significantly (p>0.05) influenced by the planting spacing *Ailanthus excelsa* and cowpea varieties. The data depicted in Table 2 revealed that cowpea varieties planted at planting spacing 10 x 10 m has maximum green fodder yield (5.45 & 5.38t/ha of cowpea variety Pusa Sukomal and 8.14 & 8.05 t/ha of cowpea variety Pusa Dharni) and dry fodder yield (9.82 & 9.69 q/ha of cowpea variety Pusa Sukomal and 15.46 & 15.29 t/ha of cowpea variety Pusa Dharni), respectively both years as compare to sole cowpea varieties. When compare among all treatments data (Table 2) highlighted that cowpea variety Pusa Dharni planted at spacing 10 x 10 m has maximum green and dry fodder yield. According to Meena *et al*. (2005) [8], intercropping fodder crops with ardu trees (Mahaneem) had a favourable effect on the ardu tree's growth and development. These parameters were also reported increased with plantation of cenchrus and cowpea in 1:2 ratios.

Table 2: Effect of different spatial arrangements on green and dry fodder yield of cowpea during 2020-21 and 2021-22

Treatment combinations		Cowpea green fodder weight (t/ha)		Cowpea dry f odder weight (q/ha)	
***Ailanthus* planting spacing (m)**	**Variety of cowpea**	**2020-21**	**2021-22**	**2020-21**	**2021-22**
Without tree	Sole cowpea variety Pusa Sukomal	4.84	4.80	8.72	8.63
10 x 20	Pusa Sukomal	4.96	4.90	8.92	8.82
10 x 10	Pusa Sukomal	5.45	5.38	9.82	9.69
10 x 6.5	Pusa Sukomal	5.03	4.95	9.05	8.91
10 x 5	Pusa Sukomal	4.86	4.82	8.76	8.68
Without tree	Sole cowpea variety Pusa Dharni	7.77	7.72	14.76	14.67
10 x 20	Pusa Dharni	7.86	7.75	14.94	14.73
10 x 10	Pusa Dharni	8.14	8.05	15.46	15.29
10 x 6.5	Pusa Dharni	7.91	7.76	15.03	14.74
10 x 5	Pusa Dharni	7.78	7.73	14.78	14.69
CD @ 5%		0.27	0.30	0.51	0.57

Total fodder production under *Ailanthus excelsa* based agroforestry system

The green and dry fodder yield of *Ailanthus excelsa* was significantly (p>0.05) influenced by the planting spacing and intercropping of cowpea varieties. The data depicted in figure 1 & 2 shows that *Ailanthus* planted at higher planting density (10 x 5 m planting spacing) has more fodder yield as compared to lower planting density (10 x 20 m planting spacing) during both experimentation year. In contrast, the cowpea varieties Pusa Dharni & Pusa Sukomal are plant in open field condition and in various *Ailanthus excelsa* spatial arrangements. The data depicted in figure 1 & 2 shows that the maximum fodder yield per year (green fodder- 12.45 & 12.17 t/ha & dry fodder- 33.79 & 32.94 q/ha during both years respectively) recorded at planting spacing 10 x 5 m intercropping cowpea variety Pusa Sukomal. Whereas, minimum fodder yield (green fodder- 4.84 & 4.80 t/ha & dry fodder- 8.72 & 8.63 q/ha, respectively) was recorded cowpea variety Pusa Sukomal planted sole during both years 2020-21 & 2021-22.

The data depicted in figure 1 & 2 shows that the maximum fodder yield per year (green fodder- 15.42 & 15.20 t/ha & dry fodder- 40.01 & 39.33 q/ha, respectively) recorded at planting spacing 10 x 5 m intercropping cowpea variety Pusa Dharni during both years. However, minimum fodder yield (green fodder- 7.71 & 7.10 t/ha & dry fodder- 16.35 & 16.06 q/ha, respectively) was recorded cowpea variety Pusa Dharni planted sole during both years 2020-21 & 2021-22. The data revealed that maximum fodder yield (green fodder- 15.42 & 15.20 t/ha & dry fodder- 40.01 & 39.33 q/ha, respectively was recorded *Ailanthus excelsa* planted at spacing 10 x 5 m with intercropping cowpea variety Pusa Dharni during both years 2020-21 & 2021-22 as compared sole planting of *Ailanthus excelsa* & cowpea (Figure 1 & 2). The reduction in fodder yield under varied spacing's 3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m, 8 × 3 m

of poplar was 81.71, 75.14, 63.00, 49.62, 39.81 and 25.60 per cent, respectively over control (sole cowpea) reported by Yadav *et al*, (2021) [22]. With an increase of 31.05% in green forage and 40.33% in dry matter over teosinte sole, Choubey *et al*. (2015) [1] found that the best yields of dry matter (90.5 q/ha) and green-forage (525.5 q/ha) were achieved when teosinte and cowpea were planted in a 2:1 planting pattern.

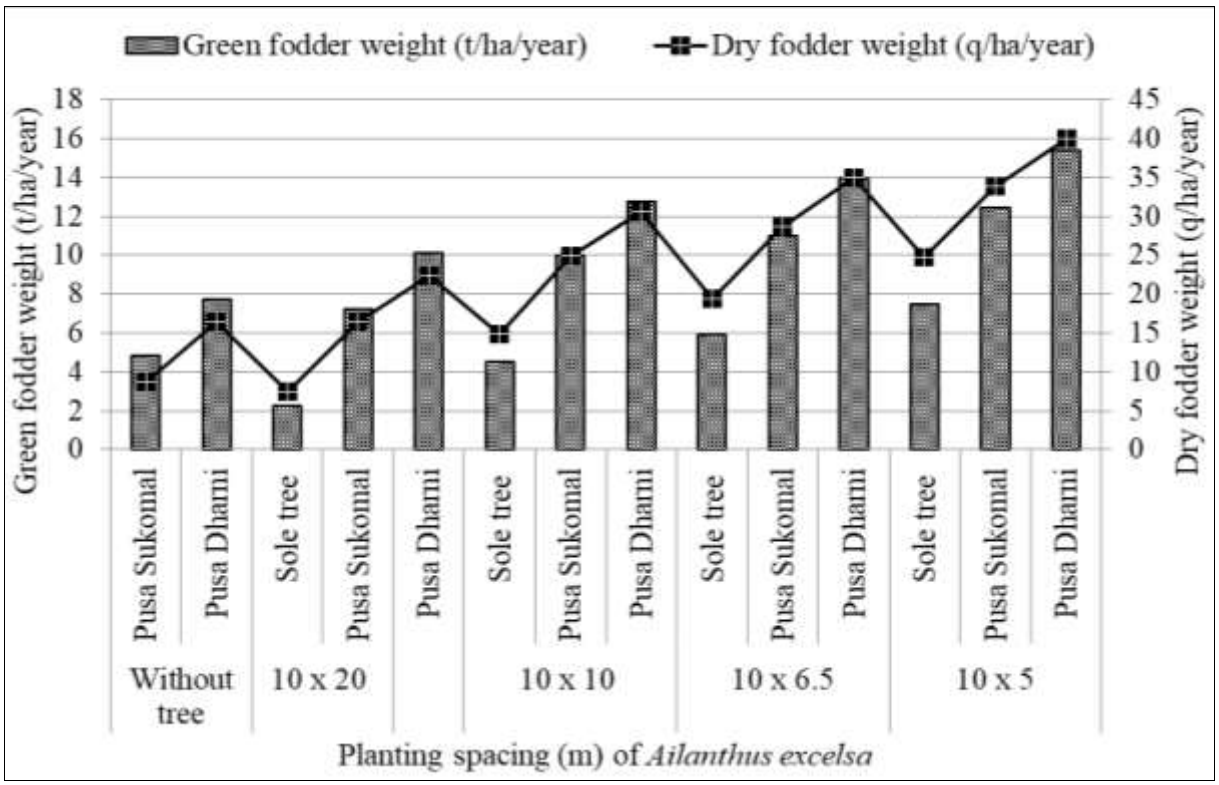

Fig 1: Total Production of green and dry fodder yield (*Ailanthus* + cowpea) under Agro-forestry System in a Semi-Arid Region of India during 2020-21

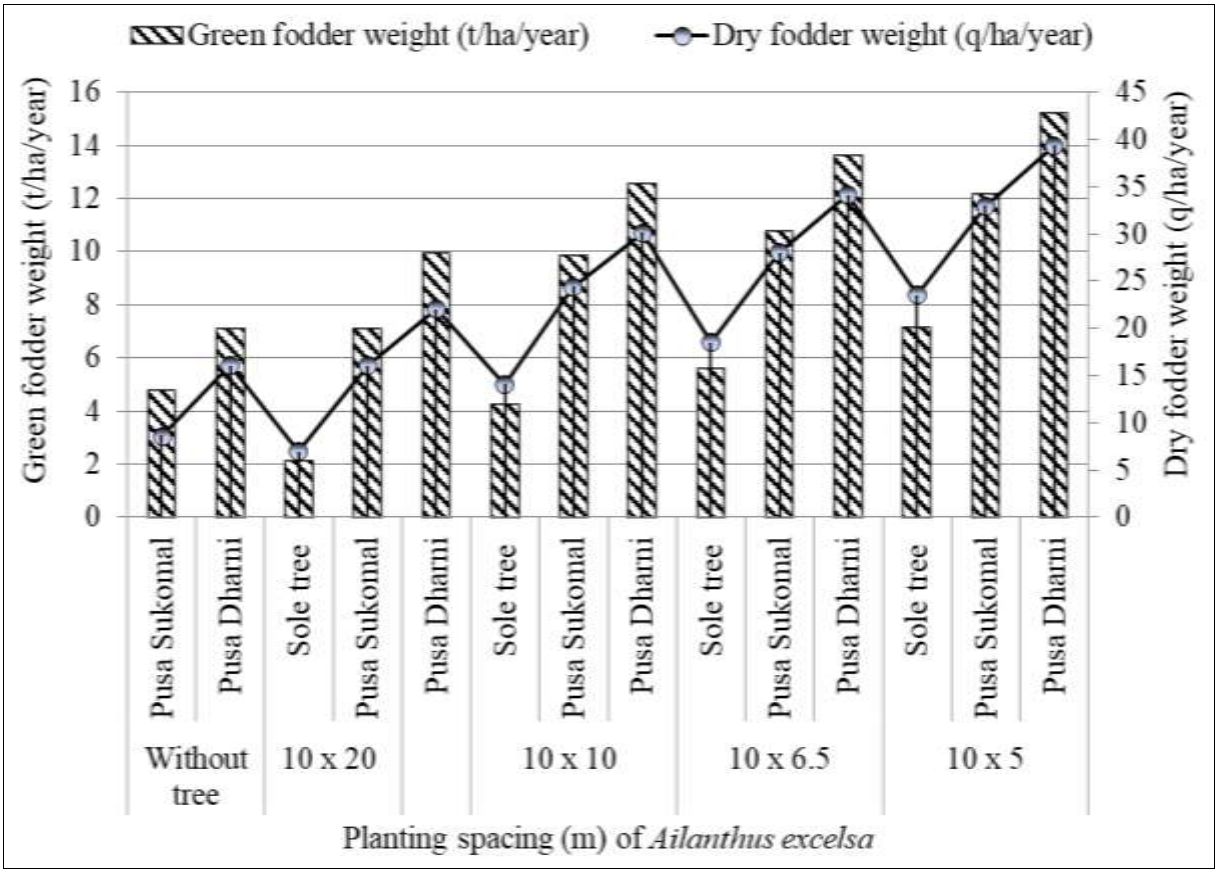

Fig 2: Total Production of green and dry fodder yield (*Ailanthus* + cowpea) under Agro-forestry System in a Semi-Arid Region of India during 2021-22

Conclusion

In semi-arid and dry regions of India and the world, intercropping cowpea under Mahaneem based agri-silviculture systems is a better way to lessen the scarcity of fodder. Pusa Sukomal and Pusa Dharni, two popular cowpea cultivars in this region were sown as intercrops in Mahaneem arrangements with varying spatial configurations to find out best combinations for higher fodder production. The results of a two-year study showed that the maximum green fodder as well as dry fodder per year was best recoded in 10 x 5 m planting spacing with intercropping cowpea variety Pusa Dharni as compared to plantation of sole tree at various planting spacing and sole plating of cowpea. Hence, 10 x 5 m planting spatial arrangement of Mahaneem with intercropping cowpea variety Pusa Dharni is recommended to the farmers for higher green fodder as well as dry fodder yield in arid and semi-arid region of Haryana, India.

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