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Evaluation of neem strains and productivity of pearl millet and cluster bean under agro-forestry system in semi-arid climate

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Abstract
In the present investigation, cultivation of pearl millet and cluster bean under neem tree plantation was undertaken at Western Regional Research Station, ICAR-IGFRI, Avikanagar. A field experiment was laid out in RBD in which one year old saplings of ten promising neem strains in 6 x 6 m plant geometry were planted. The inter spaces of plantation were used for growing of pearl millet and cluster bean during *kharif* 2011-13. Significant difference among the neem strains were observed for growth parameters *viz.,* tree height, stem diameter, number of primary branches, width of leaflet and leaf biomass production. Strain-5 showed better performance for growth parameters. Average per year growth rate of strain-5 as compared to local strain for tree height was 1.43 and 1.07 m, for DBH 3.77 and 3.10 cm, for leaf biomass production 18.6 and 15.0 kg/tree, respectively. Fodder and grain yield of pearl millet and cluster bean under neem trees decreased significantly at the age of 5 years irrespective of neem strains as compared to control (crops without neem trees). Study indicated that there was sufficient genetic variability among neem strains for selection and improvement. But planting of neem trees in 6 x 6 m geometry was not sufficient for cultivation of the pearl millet and cluster bean crops beyond 5 years age of plants.

Key words: Agro-forestry, Cluster bean, Fodder, Neem, Pearl millet, Tropics

Livestock is a vital resource for small holder farmers' livelihoods in arid and semi-arid regions of the country, but shortage of fodder is a major constraint to livestock productivity. In arid and semi-arid regions productivity of livestock is often low due to inadequate and nutritionally unbalanced supply of feed resources. Consistent supply of fodder round the year has become a great challenge for farmers especially under drought years. Pearl millet (*Pennisetum glaucum*) also known as *Bajra* contributes significantly to food and fodder security of the rural people as a dual-purpose annual crop in the arid and semi-arid tropics. It will continue to play a prominent role in the integrated agricultural and livestock economy of the country particularly in rainfed areas due to its drought hardiness and tolerance to high temperature and exceptionally highest productivity per day both for grain as well as fodder (Arya *et al.,* 2014). Cluster bean (*Cyamopsis tetragonoloba*) also known as *Guar* is another important annual legume which is well suited for cultivation in arid and semi-arid regions as sole and intercropping with pearl millet. Guar is a multi-purpose crop, used as vegetable, livestock forage/feed (fresh foliage, young pods, straw, guar meal) and variety of industrial products. Guar fodder is very nutritious for livestock as it contains 10-18% crude protein, 25-43% crude fibre, 1.5- 2.3% ether extract and 35-48% nitrogen fee extract with high dry matter digestibility in various species of livestock (Mahanta *et al*., 2001).

During the dry period (2-3 months, prior to the onset of next monsoons), farmers face considerable feed shortages and availability of quality fodder resources becomes a major limiting factor in livestock production (Ajith *et al.,* 2012). One potential avenue for improving availability of feed resources is to explore fodder from trees and bushes. Indeed, fodder trees and shrubs become more vital component in the arid and semi-arid zones where sheep and goats are mainly reared. Crude protein content of trees and shrubs are higher by 7-10% than grasses but lower in neutral detergent fibre and cellulose content than grasses (Singh and Singh, 2017). As compare to conventional grasses, tree foliage has good proportion of nutrients which keep intestinal microflora active for digesting cellulose biomass (Singh *et al.,* 2015). Neem (*Azadirachta indica*) tree is found throughout the India and successfully grown in arid, semi-arid, wet tropical and sub-tropical climates for multipurpose uses (Hegde, 1993). It can be established easily on poor, shallow, stony or sandy soils without irrigation in hot and dry regions with low annual rainfall.

Cultivation of pearl millet and cluster bean under neem tree plantation

Cultivation of crops with tree species is an age-old practice of farming systems in the arid and semi-arid climate. Food, fodder, fuel and timber production is the major aim of subsistence farmers with most of their farmland. Agri-silviculture is often practised by farmers in semi-arid regions and is perceived as a risk reducing practice. Due to reduction in rainfall and increasing trend of dairy farming, the system is becoming more important for sustainable livelihood. Therefore, in the present investigation cultivation of pearl millet and cluster bean under neem tree plantation was undertaken to workout competition studies in agri-silviculture system in semi-arid region under rainfed condition.

Ten promising neem strains acquired from Central Agroforestry Research Institute, Jhansi were planted at Western Regional Research Station of Indian Grassland and Fodder Research Institute, Avikanagar, Rajasthan for evaluating growth and morphological traits under Agri-silviculture system. The description of strains are as follows: Strain-1: F14 L4 T8/ PT-21; Strain-2: F14 L4 T14/ PT-10; Strain-3: F14 L8 T15/ PT-4; Strain-4: F14 L10 T13/ PT-13; Strain-5: F14 L16 T19/ Prov. Kota; Strain-6: F14 L8 T8/ PT-14; Strain-8: F14 L10 T4/ PT-17; Strain-9: F14 L10 T5/ F14 L10 T5; Strain-10: F14 L10 T6/ PT-17; Strain-11: F14 L13 T14/ Prov. Shivpuri and one local strain. The climate of Avikanagar is semi-arid with an average rainfall of 600 mm and mean maximum temperature varied between 40-45°C in summer and minimum of 5-6°C in winter. A field experiment was laid out in Randomised Block Design in three replications. One year old saplings were planted during the monsoon season of 2009 in a spacing of 6 m x 6 m plant geometry. The inter spaces of plantation were used for growing of fodder crops, pearl millet (Var. AVKB-19) and cluster bean (Var. Bundel Guar-1) during *kharif* season of 2011-13. These crops were sown in alternate strips of 2.1 m width by tractor operated seed drill machine. As control Pearl millet and Cluster bean crops were also cultivated without neem trees. Observations for growth parameters of neem and fodder cultivation were started at the age of 2.5 years of neem plants. Pruning (50%) of each branch was done during the month of December for recording biomass. All the leaves were detached from the pruned branches for weighing the foliage production per plant. The height and diameter at breast height (DBH) of individual tree was measured. For canopy spread average diameter of two directions was measured for each tree. Five fully developed leaves from each tree were picked at middle of tree height from all the four directions for measuring leaf length, leaf width and number of leaflet per leaf. Fruit producing ability of each strain observed visually by giving the score as below average (1), average (2), good (3), very good (4), and outstanding (5) at the age of 5.5 year. Seeds of each accession collected at the age of 6 year were de-pulped and dried to constant moisture at room temperature. Seed length, width and 1000-seed weight of ten randomly selected seeds were observed.

Analysis of variance for morphological traits of neem trees revealed that during the age of 2.5 to 5.5 years there was significant difference among the neem strains for growth parameters *viz.,* tree height, stem diameter and leaf biomass production. The difference in canopy diameter at the age of 2.5 and 3.5 was significant but at the age of 4.5 and 5.5 years it was non-significant. Most of promising strains had higher growth rate as compared to local strain for the observed parameters (Table 1 & 2). Most of the traits under study showed narrow difference between genotypic coefficient of variation and phenotypic coefficient of variation which showed strong genetic control (Table 3). Traits *viz.,* number of primary branches and width of leaflet showed significant difference, while leaf length, number of leaflet per leaf and leaflet length were not significantly differed. The strain-5 belongs to Kota province (Rajasthan) showed best performance for almost all the characters. The high foliage of strain-5 was contributed through number of branches, number of leaves, number of leaflets per leaf and leaf area. On the basis of growth parameters observed during four years (2011-14) strain-5 found best followed by strain-3. The average per year growth rate of strain-5, strain-3 and local strain for tree height was 1.43, 1.37 and 1.07 m, for DBH 3.77, 3.90 and 3.10 cm and for leaf biomass production 18.6, 18.5 and 15.0 kg/tree, respectively. Oil and Azadirachtin content are most important economic traits of a neem strain and strain-5 was placed under medium class for these traits (Gupta *et al.,* 2010). Significant variation for plant height, collar diameter and survival rate of six neem provenances were measured at three test sites in Bangladesh and India that were classed as optimum, intermediate and stress environments for neem (Kundu *et al*., 1998). There were significant differences between provenances for height and collar diameter, and genotype x environment effect for height. The authors suggested that rainfall and temperature might be the environmental factors affecting variation in growth characteristics. Significant variations for growth characteristics *viz*., tree height, collar diameter, diameter at breast height (DBH), clear bole length and canopy diameter of 13-year-old trees grown at CAZRI, Jodhpur, were also reported earlier (Jindal *et al*., 1999).

Table 1. Growth parameters of neem strains under semi-arid conditions during 2011-14

Neem strain	Plant height (m)				Stem diameter at breast height (cm)				Canopy diameter (m)				Biomass (kg/plant)		
	2.5 year	3.5 year	4.5 year	5.5 year	2.5 year	3.5 year	4.5 year	5.5 year	2.5 year	3.5 year	4.5 year	5.5 year	3.5 year	4.5 year	5.5 year
Local	2.6	4.1	5.0	5.8	3.2	6.0	09.7	12.5	1.3	2.9	3.9	4.8	3.9	19.6	33.9
Strain-1	3.4	5.0	5.4	6.3	4.8	7.2	13.3	15.6	1.9	3.4	3.8	4.8	12.4	22.4	37.8
Strain-2	3.7	5.0	5.8	6.4	5.2	7.3	13.6	15.2	2.0	3.4	4.0	5.0	10.0	17.8	32.2
Strain-3	3.9	5.0	6.7	8.0	5.5	7.8	15.2	17.2	2.3	3.8	4.0	5.5	10.8	28.6	47.7
Strain-4	3.7	4.9	5.7	6.4	4.6	7.5	10.9	15.3	2.1	3.6	4.4	5.4	9.3	19.6	36.3
Strain-5	3.8	5.2	6.9	8.1	5.3	7.8	15.6	16.6	2.2	3.4	4.4	6.1	15.6	31.3	52.7
Strain-6	3.9	5.1	5.8	6.6	4.3	5.9	11.5	13.3	1.7	3.3	4.2	5.0	8.0	19.1	37.3
Strain-8	3.7	4.9	5.8	6.8	5.0	6.9	13.9	14.5	2.0	3.2	4.6	5.7	11.6	25.1	40.5
Strain-9	3.8	5.3	5.5	6.4	5.5	7.5	13.2	17.3	2.0	3.4	4.1	4.9	10.9	22.6	36.6
Strain-10	3.8	4.8	5.9	6.9	5.8	7.7	15.4	16.8	2.2	3.7	4.0	5.4	11.6	24.2	43.4
Strain-11	3.8	5.0	5.1	6.0	5.1	7.1	13.2	15.3	2.1	3.3	3.8	4.7	7.7	20.5	34.9
Mean	3.6	4.9	5.8	6.7	4.9	7.2	13.4	15.4	2.0	3.4	4.1	5.2	10.2	22.8	39.4
CD (5%)	0.47	0.59	1.0	0.62	0.78	0.92	1.7	2.33	0.43	0.45	NS	0.83	2.83	3.73	10.21

Table 2. Morphological traits of neem strains at 5.5 years age under semi-arid conditions

Neem strain	No. of primary branches	Leaf length (cm)	No. of leaflets/leaf	Length of leaflet (cm)	Width of leaflet (cm)	Fruit bearing score (1-5 scale)
Local	4.0	38.0	17.2	6.9	2.6	2.6
Strain-1	4.6	29.3	17.4	6.6	1.6	4.0
Strain-2	4.6	35.2	16.6	6.9	2.1	2.3
Strain-3	5.5	32.8	15.6	7.3	1.8	2.3
Strain-4	3.5	33.3	17.1	7.5	2.1	3.5
Strain-5	5.6	36.3	18.7	7.0	2.1	4.3
Strain-6	3.8	31.4	16.7	6.7	1.7	3.0
Strain-8	4.3	31.8	16.1	6.8	1.9	4.0
Strain-9	4.8	32.2	17.7	6.7	2.1	2.8
Strain-10	5.2	36.1	18.3	7.0	2.2	3.3
Strain-11	4.4	30.7	16.9	7.4	1.7	3.0
Mean	4.6	33.4	17.1	7.0	2.0	3.3
CD (5%)	1.42	NS	NS	NS	0.52	0.6

Table 3. Estimate of genetic parameters for morphological traits of neem strains

Character	Mean	Range	GCV	PCV
Plant height (cm)	6.7	5.4-8.6	10.51	10.92
Stem diameter at breast height (cm)	15.4	11.8-18.4	7.44	8.84
Canopy diameter (m)	5.2	4.3-6.7	6.25	8.27
Biomass (kg/plant)	39.4	28.3-56.2	13.21	15.87
No. of primary branches	4.6	3.4-5.9	14.05	14.60
Leaf length (cm)	33.4	29.3-38.2	7.19	7.56
No. of leaflets/leaf	17.1	14.9-19.8	3.59	4.99
Length of leaflet (cm)	7.0	6.1-7.9	2.50	4.06
Width of leaflet (cm)	2.0	1.4-2.8	12.78	13.82

The fodder and grain yields of pearl millet and cluster bean under neem trees were found non-significant up to the age of 4 years, while at the age of 5 years the fodder and grain yield both decreased significantly irrespective of neem strains as compared to control (crops without neem trees; Table 4). The reduction in productivity of crops was due to shading effects. Cluster bean crop found highly sensitive to the shade as it was infested by powdery/downy mildew disease under shade. On the other hand pearl millet crop become vulnerable to bird damage due to tree plantation. The mean dry fodder and grain yield of pearl millet was 79.0 and 8.5 q/ha, respectively during 2012 which was reduced by 45 and 44%, during 2013 as compared to 2012. The mean dry fodder and grain yield of cluster bean was 33.3 and 8.0 q/ha, respectively, during 2012 which was reduced by 44 and 35%, during 2013 as compared to 2012. Nagar *et al.* (2010) observed mean dry fodder and grain yield of 80.2 and 13.1 q/ha, respectively from dual propose variety AVKB-19 as sole crop. Meena and Nagar (2017) reported 54 q/ha mean dry fodder yield of promising cluster bean germplasm as sole crop. Osman *et al.* (1998) studied performance of sorghum and cowpea under agri-silviculture system with *Leucaena leucocephala* trees and reported that grain yields of sorghum with no root barriers were 76% and 39% of pure crop yield (15.5 q/ha) for pruned and unpruned trees, respectively. Corresponding values for cowpea were 49 % and 26 % of pure crop yield (10.6 q/ha). Similarly, a study conducted at Jhansi on the tree-crop interaction in *Albizia procera* and black gram and mustard agri-silviculture system, showed that there was significant reduction in crop yield due to the limited availability of light to the crop (Newaj *et al.,* 2003). Thakur and Dutt (2003) also reported adverse effect on photosynthesis, transpiration and water use efficiency of wheat attributed to the shade effect of *Morus alba* under rainfed conditions. In contrast to present findings, Rao *et al.* (2000) observed higher dry matter, crop growth rate, leaf area and leaf area index in groundnut under alley cropping with *Albizia* than in sole cropping. Kaushik and Kumar (2003) reported positive effect of 20-year old *Prosopis cineraria* trees on the grain and fodder yield of arable crops under rainfed conditions. Green and dry fodder yield during both *kharif* and *rab*i seasons was more in association with *P. cineraria* trees as compared to sole cropping of fodder crops.

It was inferred that there was sufficient genetic variability among neem strains studied for selection and improvement. But planting of neem trees in 6 x 6 m geometry was not sufficient for cultivation of the pearl millet and cluster bean crops beyond 5 years age of plants. Since fodder as well as grain yields of pearl millet and cluster bean under neem trees decreased significantly at the age of 5 years irrespective of neem strains when compared to crops without neem trees.

Table 4. Fodder and grain production of pearl millet and cluster bean under agro-forestry system

Treatment	Bajra dry fodder yield (q/ha)			Guar dry fodder yield (q/ha)			Bajra grain yield (q/ha)			Guar grain yield (q/ha)		
	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
T1	82.7	81.6	46.2	34.7	34.2	18.5	9.3	9.1	5.1	8.9	8.9	3.7
T2	78.7	78.2	36.4	33.7	33.3	14.6	8.8	9.0	3.6	7.5	7.8	2.5
T3	80.1	78.5	34.6	32.2	34.7	14.8	8.7	6.4	3.5	8.0	7.7	2.8
T4	82.6	82.5	34.4	34.5	33.4	14.5	8.4	8.1	3.9	8.0	8.1	2.7
T5	83.2	82.8	35.0	33.4	33.6	16.1	8.8	8.7	3.7	8.4	8.1	2.7
T6	78.1	77.6	37.7	34.3	33.7	15.1	8.4	9.0	3.8	8.0	8.0	2.6
T7	78.7	76.8	35.9	32.8	32.3	14.1	8.4	8.9	3.7	8.1	8.3	2.8
T8	77.5	75.7	34.2	34.2	33.1	13.7	8.3	9.2	3.5	7.8	8.1	2.8
T9	78.2	77.8	33.9	33.1	32.8	14.0	7.7	8.4	3.6	7.6	8.0	2.8
T10	78.3	78.0	33.0	33.1	32.6	14.5	8.3	8.3	3.5	7.8	8.2	2.5
T11	79.2	80.6	33.7	32.9	33.0	13.8	8.9	8.7	3.2	7.6	7.8	2.9
T12	79.2	77.7	33.3	32.5	32.8	13.9	8.0	8.0	3.4	7.9	7.4	2.8
Mean	79.7	79.0	35.5	33.4	33.3	14.8	8.5	8.5	3.7	8.0	8.0	2.8
CD (5%)	5.0	NS	6.7	2.1	NS	2.6	1.1	NS	0.9	0.8	NS	0.6

T_1: Fodder without Neem tree (control); T_2: Local strain+Bajra+Guar; T_3: Strain-1+Bajra+Guar; T_4: Strain-2 +Bajra+Guar; T_5: Strain-3+Bajra+Guar; T_6: Strain-4+Bajra+Guar; T_7: Strain-5+Bajra+Guar; T_8: Strain-6+Bajra+Guar; T_9: Strain-8+Bajra+Guar; T_{10}: Strain-9+Bajra+Guar; T_{11}: Strain-10+Bajra+Guar; T_{12}: Strain-11+Bajra+Guar

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