A-5533
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RESEARCH ARTICLE Indian Journal of Agricultural Research

Yield and Nutrition of Moth Bean-Mustard Rotation in Soils Amended with Tree Leaf Litters in the Arid Region of Rajasthan

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10.18805/IJARe.A-5533

ABSTRACT

Background: The incorporation of leaf litters in agroforestry systems can meet a significant share of nutrients demand and improve crop yield. The *Citrus aurontifolia, Aegle marmelos* and *Cordia myxa* (among fruit trees) and *Colophospermum mopane*, *Acacia senegal, Acacia tortilis, Dalbergia sissoo* (among trees) are well-adapted species to the arid environment. Unfortunately, little work has been done in the past to study the influence of leaf litters of these species on yield and nutrition of crops grown in arid region. Therefore, the present experiment was planned to study the influence of leaf litters of *Colophospermum mopane*, *Acacia senegal, Acacia tortilis, Dalbergia sissoo*, *Citrus aurontifolia, Aegle marmelos* and *Cordia myxa* on yield and uptake of nutrients in moth bean and Indian mustard in arid region.

Methods: Field experiment was conducted at ICAR-Central Arid Zone Research Institute, Regional Research Station, Bikaner in moth bean-mustard rotation during 2010-11 and 2011-12 by incorporating leaf litters of seven tree species i.e. Mopane (*Colophospermum mopane*), Gum acacia (*Acacia Senegal*), Umbrella tree (*Acacia tortilis*), Indian rosewood (*Dalbergia sissoo*), Sour lime (*Citrus aurantifolia*), Assyrian plum (*Cordia myxa*) and Bengal quince (*Aegle marmelos*) in randomized block design with three replications. Grain and straw yield was recorded and analysed for N, P and K content.

Result: The maximum grain yield of moth bean and its residual effect on mustard was observed in the soils amended with leaf litters of *Citrus aurontifolia* followed by *Aegle marmelos* and *Dalbergia sissoo*. The total uptake of N, P and K was significantly higher in the treatments of *Citrus aurontifolia* and *Aegle marmelos*, which was due to the higher dry matter production of crops, faster rate of litter decomposition and higher release of nutrients.

Key words: Leaf litters, Moth bean, Mustard, Nitrogen, Phosphorus, Potassium, Yield.

INTRODUCTION

Soils in the arid regions are often poor in fertility as they are coarse in texture, low in organic carbon (0.05-0.20%), low in nitrogen (0.028-0.05%), low-to-medium levels of available phosphorous (10-25 kg ha^{-1}), low vegetation cover and high temperatures (Kumar *et al.*, 2009). They are prone to wind erosion (Kar *et al.*, 2009) which affects agricultural production directly through crop damage and indirectly through loss in soil fertility (Soni *et al.,* 2013; Santra *et al*., 2017). Over the last two decades, a great emphasis is being laid on the development of arid lands through various agroforestry systems *viz*. agri-horti, agri-silvi, agri-pasture models (Sharma, 2009; Soni *et al.,* 2013; Yadava *et al.*, 2017). The perennial components of these agri-horti or agri-silvi systems play a great role in nutrient cycling and energy transfer in soil-plant systems (Singh, 1971). Through the process of litter decomposition and mineralization, the unavailable form of nutrients *viz*. N and P contained in leaf litters get converted into more available form and a significant amount of nutrients are released which increase the yield of associated intercrops in agroforestry systems (Bhatt *et al.,* 1997; Singh *et al.,* 1998; Groffman *et al*., 1996; Rasal and Patil, 1993).

The *Citrus aurontifolia, Aegle marmelos and Cordia myxa* (Among fruit trees) and *Colophospermum mopane*, *Acacia senegal, Acacia tortilis, Dalbergia sissoo* (Among trees) are well-adapted species to the arid environment under limited water conditions. Litterfall from these species are variable (CAZRI, 2016) and may play a vital role to improve soil organic matter and nutrients release. The studies have shown that the nutrient release behaviour differs from species to species depending upon the chemistry of leaf litters (Soni *et al.*, 2016 and Meena *et al*., 2018), soil properties, weather conditions and population of soil microorganisms (Mugendi and Nair, 1997; Singh and Sharma, 2007). Unfortunately, little work has been done in the past to study the influence of leaf litters of these species on yield and nutrition of crops grown in the arid region. Moth bean (*Vigna aconitifolia* Jacq.) is an important arid legume

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How to cite this article: Soni, M.L., Subbulakshmi, V., Verma, A., Yadava, N.D. and Nathawat, N.S. (2020). Yield and Nutrition of Moth Bean-Mustard Rotation in Soils Amended with Tree Leaf Litters in the Arid Region of Rajasthan. Indian Journal of Agricultural Research.

Submitted: 18-02-2020 **Accepted**: 16-07-2020 **Published**:

consumed in the form of different food preparations. Its contribution is enormous in the rural economy of this region. Indian mustard [*Brassica juncea* (L.)] is also a less water requiring crop and grown for edible oil value. Therefore, the present experiment was conducted with the objective to study the influence of leaf litters of *Colophospermum mopane*, *Acacia senegal, Acacia tortilis, Dalbergia sissoo*, *Citrus aurantifolia, Aegle marmelos* and *Cordia myxa* on yield and uptake of nutrients in moth bean and Indian mustard in the arid region.

MATERIALS AND METHODS

Site characteristics

The soils of the experimental site were alkaline ($pH_{(1:2)}$=8.2), $EC_{(1:2)}$=0.22 dS m^{-1}), loamy sand in texture with low soil organic carbon (0.09 percent) and poor in nutrient status (available N, P and K are 92.2, 11.4 and 224.2 kg ha^{-1}, respectively). The details of the soil characteristics determined by their standard methods (Jackson, 1973) have been given in Table 1.

Field Study

Field experiment was conducted at the research farm of ICAR-Central Arid Zone Research Institute, Regional Research Station, Bikaner in moth bean-mustard rotation during 2010-11 and 2011-12 in micro plots (2X2 m) by adding leaf litters of seven tree species i.e. Mopane (*Colophospermum mopane)*, Gum acacia (*Acacia senegal),* Umbrella tree (*Acacia tortilis),* Indian rosewood (*Dalbergia sissoo)*, Sour lime (*Citrus aurantifolia),* Assyrian plum (*Cordia myxa) and* Bengal quince (*Aegle marmelos)* in randomized block design (RBD) with three replications. Litterfall of these species was collected from the surface floor of already established agri-horti/agri-silvi systems. They were dried, chopped, analysed for litter chemistry (Table 2) and stored for application in the field.The leaf litter was applied @ 2.5 Mg ha^{-1} (Dry weight basis) and the chemical fertilizers were applied as per the recommended dose of individual crops and mixed thoroughly in the soil. Other management practices *viz*. irrigation, insect-pest management, weed management, etc. were followed as per the requirement of the crop. Grain and straw yield was recorded at maturity. The samples of grain and straw were ground and analysed for N, P and K content by adopting standard protocols (Piper, 1966). The nutrient uptake by plants was calculated by multiplying the concentration of these nutrients with the yield of crops in the respective component. Lignin was estimated by using the method given by Van Soest *et al.* (1991). After harvesting the crops, the soil samples were collected from the upper 0.15 m soil depth from each plot and analysis for available N, P and K.

Table 1: Physico-chemical properties of experimental soil.

Parameters	Values
$pH_{(1:2)}$	8.2
$EC_{(1:2)}$ (dS m^{-1})	0.22
Organic carbon (%)	0.09
Available N (kg ha^{-1})	92.2
Available P (kg ha^{-1})	11.4
Available K (kg ha^{-1})	224.2
Sand (%)	88.2
Silt (%)	7.2
Clay (%)	4.6
Soil Texture	Loamy sand

Statistical Analysis

Data were statistically analyzed by the F test to examine the treatment effects at 5 percent level of significance (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Chemical properties of leaf litter

Among different species, *Cordia myxa was* lowest in nitrogen (0.93%) and highest in C/N ratio (53.1) followed by *Colophospermum mopane* (Table 2). Lowest C/N ratio was observed in *Acacia tortilis followed by Citrus aurontifolia.* The lignin content was maximum (45.5%) in the *Cordia myxa* and minimum in *A. senegal* (12.6%). There was no much variation in lignin content of *A. senegal* and *A. tortilis*.

Growth and yield

The plant height, grain yield and straw yield of moth bean increased significantly in litter amended soils as compared to control (Table 3). The maximum grain yield of moth bean was observed in the treatment of *Citrus aurontifolia* litters followed by *Aegle marmelos*. An increase in grain yield of moth bean was observed to the tune of 19.5, 15.5 and 3.8 percent in 2010-11 and 21.4, 18.3 and 16.9 percent in 2011-12 with the leaf litters of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo*, respectively. The higher yield of moth bean in 2011-12 was due to more rainfall in cropping season (368 mm) as compared to the cropping season of the year

Table 2: Nutrient content, C:N ratio and lignin content of leaf litters used in the experiments (Values are mean ± S.E.).

Tree species	Nitrogen (%)	Phosphorus (%)	Potassium (%)	C: Nratio	Lignin (%)
Colophospermum mopane	0.99 ± 0.06	0.16±0.01	1.11+ 0.03	50.5 ± 3.26	34.12 ± 0.16
Citrus aurontifolia	2.17 ± 0.04	0.21±0.01	1.48+ 0.03	22.7 ± 0.4	19.80 ± 0.50
Dalbergia sissoo	1.51 ± 0.06	0.29±0.02	0.73+ 0.02	32.9 ± 1.63	16.16 ± 1.35
Acacia tortilis	2.18 ± 0.03	0.26±0.02	0.98+ 0.07	20.3 ± 0.51	13.53 ± 0.99
Aegle marmelos	1.66 ± 0.03	0.19±.010	1.45+ 0.03	25.9 ± 0.7	15.40 ± 1.30
Cordia myxa	0.93 ± 0.04	0.12±0.01	1.78+ 0.02	53.1 ± 0.9	45.50 ± 2.50
Acacia senegal	1.76 ± 0.06	0.21±0.01	1.40+0.09	24.2 ± 1.18	12.65 ± 0.38

2010-11 which received 281mm rainfall. Leaf litters of *Colophospermum mopane, Cordia myxa*, *Acacia tortilis* and *Acacia senegal* showed no significant effect on grain yield.

The residual effect of leaf litters (incorporated to moth bean) on mustard showed that the plant height, grain and straw yield of mustard grown after moth bean was significantly affected by leaf litter of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* as compared to control (Table 4). Relatively higher plant height, grain and straw yield were observed in the treatment of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* as compared to other treatments. The increase in grain yield was 14.5, 15.5 and16.9 percent in 2010-11 and 13.9, 15.0 and 15.9 percent in 2011-12 with the leaf litters of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo*, respectively. Similarly, the straw yield was increased by 15.3, 12.4 and 13.6 percent in 2010-11 and 18.5, 16.3 and 16.7 percent in 2011-12 with the leaf litters of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo*, respectively.

The possible reason for better yield in litter amended soils might be ascribed to the higher nutrient availability for the crops supplied by leaf litters (Escalada and Ratilla, 1998; Singh *et al.,* 1998; Kumar *et al*., 2001; Khatun *et al.,* 2010). Soni *et al.* (2013, 2016) observed that the release of nutrients during litter decomposition is affected by C:N ratio and lignin content. Due to the lower lignin content of leaf litters of *Citrus aurontifolia* (19.8%), *Aegle marmelos* (15.4%) and *Dalbergia sissoo* (16.2%), in comparison to *Cordia myxa* (45.5%) and *Colophospermum mopane* (34.1%), the rate of decomposition of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* was faster as compared to *Cordia myxa* and *Colophospermum mopane* and higher nutrient release occurred. The lignin content and C:N ratio of *Acacia senegal* and *Acacia tortilis* was not high (Lignin content = 13.5 and 12.6 and C: N ratio was 20.3 and 24.2 in *Acacia tortilis* and *Acacia senegal*, respectively), even though, the yield was not increased with the leaf litters of these two species. This may be due to the presence of some allelopathic compound which may interact with the nutrient release and affect the growth and yield of crops. Studies conducted elsewhere have shown good evidences of the existence of alkaloids and phenolic compounds in the leaves of *Acacia tortilis* and their inhibitory effect on germination and crop growth (Nakafeero *et al*., 2007; Noumi and Chaieb, 2011).

Nutrient uptake

Litter addition had a significant effect on nutrient uptake in both the crops in both the years. The uptake of nutrients in moth bean was significantly higher in *Citrus aurontifolia*,

Table 3: Effect of leaf litters on yield and yield attributes of moth bean.

Treatments	Height (cm)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Ct	18.7	18.7	18.7	279.2	299.2	289.2	1137.5	1150.8	1144.1
Cm	25.7	21.7	23.7	283.3	313.3	298.3	1154.2	1140.9	1147.5
Ca	20.3	24.3	22.3	333.3	363.3	348.3	1270.9	1232.5	1251.7
Ds	19.7	19.9	19.7	290.0	350.0	320.0	1439.2	1379.2	1409.2
At	19.6	19.8	19.7	274.2	314.2	294.2	1165.0	1130.0	1147.5
Am	27.5	27.9	27.7	314.2	354.2	334.2	1309.1	1256.6	1282.8
Co	26.7	21.5	24.1	285.8	335.8	310.8	1360.0	1258.0	1309
As	21.0	21.2	21.1	298.3	328.3	313.3	1147.5	1146.7	1147.1
LSD (0.05)	5.34	3.41	-	32.87	45.8	-	90.46	75.8	-

Ct-Control, Cm=Colophospermum mopane, Ca=Citrus aurontifolia, Ds=Dalbergia sissoo, At= Acacia tortilis, Am=Aegle marmelos, Co=Cordia myxa, As=Acacia senegal.

Table 4: Effect of leaf litters on yield and yield attributes of mustard.

Treatments	Height (cm)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Ct	137.0	146.7	141.8	959.9	995.9	977.9	2662.0	2796.3	2729.1
Cm	139.3	148.6	143.9	980.7	1016.7	998.7	2744.4	2974.1	2859.2
Ca	154.8	165.2	160.0	1098.8	1134.8	1116.8	3071.6	3314.8	3193.2
Ds	157.9	167.9	162.9	1118.9	1154.8	1136.8	3025.7	3263.0	3144.3
At	139.8	149.2	144.5	1038.9	1074.8	1056.8	2817.6	3074.1	2945.8
Am	150.6	160.6	155.6	1109.3	1145.2	1127.2	2992.5	3251.9	3122.2
Co	142.7	149.5	146.1	979.2	1015.2	997.2	2655.1	2851.9	2753.5
As	138.2	147.6	142.9	942.2	978.1	960.1	2460.8	2548.1	2504.4
LSD (0.05)	4.5	6.1	-	129.7	122.7	-	283.9	292.8	-

Ct-Control, Cm=Colophospermum mopane, Ca=Citrus aurontifolia, Ds=Dalbergia sissoo, At= Acacia tortilis, Am=Aegle marmelos, Co=Cordia myxa, As=Acacia senegal.

Aegle marmelos and *Dalbergia sissoo* amended litter than control (Table 5). The N uptake data averaged over both the years showed that the uptake of N by the grains of moth bean was highest in *Citrus aurontifolia* litter amended soils followed by *Aegle marmelos*. There was a non-significant difference in N uptake of grains of moth bean in *Colophospermum mopane*, *Cordia myxa* and *Acacia senegal* amended litters as compared to control. The total uptake of N (averaged over both the years) in moth bean increased from 23.5 kg ha^{-1} in control to 35.8, 31.6 and 34.3 kg ha^{-1} in *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* amended litters, respectively. Similarly, the total uptake of P (averaged over both the years) in moth bean increased from 4.9 kg ha^{-1} in control to 6.3, 5.8 and 6.4 kg ha^{-1} and uptake of K increased from 10.9 to 14.4, 13.3 and 14.4 kg ha^{-1} in *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* amended litters, respectively.

The residual effect of leaf litters on nutrient uptake in grain and straw of mustard showed relatively higher nutrient uptake in the treatments of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* leaf litter as compared to *Colophospermum mopane*, *Cordia myxa*, *Acacia tortilis* and *Acacia senegal* (Table 6). The total N uptake (Seed + straw) in mustard (Pooled data of both the years) increased from 48.0 kg ha^{-1} in control to 59.8, 59.4 and 58.3 kg ha^{-1} with *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* amended litters, respectively. Similarly, the total P uptake in mustard increased from 14.1 kg ha^{-1} in control to 17.7, 16.4 and 15.2 kg ha^{-1} with *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* amended litters, respectively. The total K uptake in mustard increased from 70.2 kg ha^{-1} in control to 80.7, 81.3 and 76.8 kg ha^{-1} with *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* amended litters, respectively.

The release of nutrients from leaf litters depends upon their rate of decomposition which is governed by C:N ratio, lignin content, polyphenols, etc. The easily decomposed plant materials are termed as good quality litters. They release the nutrients faster and results in higher uptake of nutrients by the crops (Uyoybisere and Elemo, 2002). In the present study, the higher uptake of nutrients in *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* litter amended soils was due to their better quality leaf litters in terms of low C:N ratio and low lignin content which enhance the rate of litter decomposition, faster release of nutrients and higher yield than the poor quality leaf litters of *Cordia myxa*, *Colophospermum mopane*, *Acacia senegal* and *Acacia tortilis* (Soni *et al.*, 2013 and 2016). Furthermore, the total quantity of nitrogen applied through leaf litters was relatively higher in *Citrus aurontifolia* (54.2 kg ha^{-1}), *Dalbergia sissoo* (41.4 kg ha^{-1}) and *Aegle marmelos* (37.8 kg ha^{-1}) as compared to *Colophospermum mopane* (24.8 kg ha^{-1}) and *Cordia myxa* (23.3 kg ha^{-1}) and the N release in *Citrus aurontifolia*, *Aegle marmelos and Dalbergia sissoo* during the cropping season (July to October) was 54.1, 47.6 and 11.4% of the total nitrogen contained in these litters (Soni *et al.,* 2013), which showed significant effect on nitrogen uptake by the crops.

Table 5: Effect of different tree leaf litters on the nutrient uptake by Mothbean.

Treatments	N uptake (kg ha^{-1})					P uptake (kg ha^{-1})					K uptake (kg ha^{-1})				
	Grain			Straw		Grain			Straw		Grain			Straw	
	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Ct	8.9	9.5	9.2	14.6	14.0	14.3	1.5	1.5	1.5	3.2	3.7	3.4	0.8	0.9	0.8	10.0	10.2	10.1
Cm	9.4	10.4	9.9	16.7	16.1	16.4	1.5	1.6	1.6	3.3	3.7	3.5	0.9	1.1	1.0	10.5	10.5	10.5
Ca	12.8	14.1	13.4	22.8	22.1	22.4	2.0	2.1	2.0	4.0	4.5	4.3	1.2	1.5	1.3	12.7	13.4	13.1
Ds	9.8	11.9	10.8	23.9	23.1	23.5	1.6	1.9	1.7	4.3	4.9	4.6	0.9	1.4	1.1	13.1	13.6	13.3
At	8.8	10.1	9.5	17.6	16.9	17.2	1.4	1.6	1.5	3.6	4.0	3.8	0.8	0.9	0.8	10.9	11.6	11.2
Am	11.4	12.7	12.1	19.8	19.2	19.5	1.7	1.9	1.8	3.8	4.1	4.0	1.1	1.3	1.2	11.9	12.3	12.1
Co	8.9	10.6	9.8	17.5	16.7	17.1	1.5	1.7	1.6	3.8	4.0	3.9	0.9	1.1	1.0	12.4	12.4	12.4
As	9.3	10.5	9.9	15.4	14.8	15.1	1.6	1.7	1.6	3.3	3.6	3.5	0.9	0.9	0.9	10.0	10.0	10.0
LSD (0.05)	1.3	2.0	1.7	1.9	1.9	1.9	0.2	0.3	0.2	0.6	0.5	0.5	0.2	0.3	0.2	1.4	1.4	1.4

Ct-Control, Cm=Colophospermum mopane, Ca=Citrus aurontifolia, Ds=Dalbergia sissoo, At= Acacia tortilis, Am=Aegle marmelos, Co=Cordia myxa, As=Acacia senegal.

Table 6: Effect of different tree leaf litters on the nutrient uptake by mustard.

Treatments	N uptake (kg ha^{-1})						P uptake (kg ha^{-1})						K uptake (kg ha^{-1})					
	Grain			Straw			Grain			Straw			Grain			Straw		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Ct	27.6	28.2	27.9	19.5	20.7	20.1	6.1	6.4	6.2	7.8	7.8	7.8	10.6	11.5	11.0	59.8	58.5	59.1
Cm	28.7	29.5	29.1	20.3	22.2	21.3	6.0	6.4	6.2	7.7	8.0	7.8	11.0	11.6	11.3	58.7	63.3	61.0
Ca	34.5	35.2	34.8	23.7	26.3	25.0	7.6	7.8	7.7	9.4	10.6	10.0	12.1	13.8	13.0	66.5	69.0	67.8
Ds	34.6	35.0	34.8	22.4	24.6	23.5	6.6	7.1	6.8	8.1	8.7	8.4	12.6	12.8	12.7	62.7	65.6	64.1
At	31.1	32.3	31.7	21.3	23.4	22.3	6.5	6.9	6.7	7.3	8.0	7.7	10.8	11.9	11.4	52.6	59.7	56.1
Am	37.0	35.5	36.2	22.4	23.8	23.1	7.4	7.4	7.4	8.8	9.1	8.9	12.3	13.2	12.7	65.8	71.2	68.5
Co	30.4	31.8	31.1	20.3	21.2	20.8	6.3	6.5	6.4	7.4	7.8	7.6	10.8	13.6	12.2	61.4	59.8	60.6
As	28.6	29.3	28.9	18.7	18.9	18.8	5.6	5.9	5.8	7.0	6.6	6.8	11.5	11.9	11.7	53.4	55.2	54.3
LSD (0.05)	4.8	5.2	5.0	3.0	2.4	2.7	1.1	1.0	1.1	1.2	1.7	1.4	1.4	2.0	1.7	9.2	8.6	8.9

Ct-Control, Cm=Colophospermum mopane, Ca=Citrus aurontifolia, Ds=Dalbergia sissoo, At= Acacia tortilis, Am=Aegle marmelos, Co=Cordia myxa, As=Acacia senegal.

Table 7: Average N, P and K content of soil (After 2 years) after harvest of mustard incorporated with different leaf litters.

Treatments	Available nutrients (kg ha^{-1})		
	N	P	K
Ct	92.0	11.2	216.0
Cm	98.2	12.8	222.1
Ca	114.6	13.2	221.2
Ds	106.8	13.6	218.3
At	110.5	13.4	224.6
Am	108.4	13.3	216.8
Cm	97.2	11.8	226.1
As	108.2	13.2	220.3
LSD (0.05)	6.62	0.75	NS

Ct-Control, Cm=*Colophospermum mopane, Ca=Citrus aurontifolia, Ds=Dalbergia sissoo, At= Acacia tortilis, Am=Aegle marmelos, Co=Cordia myxa, As=Acacia senegal.*

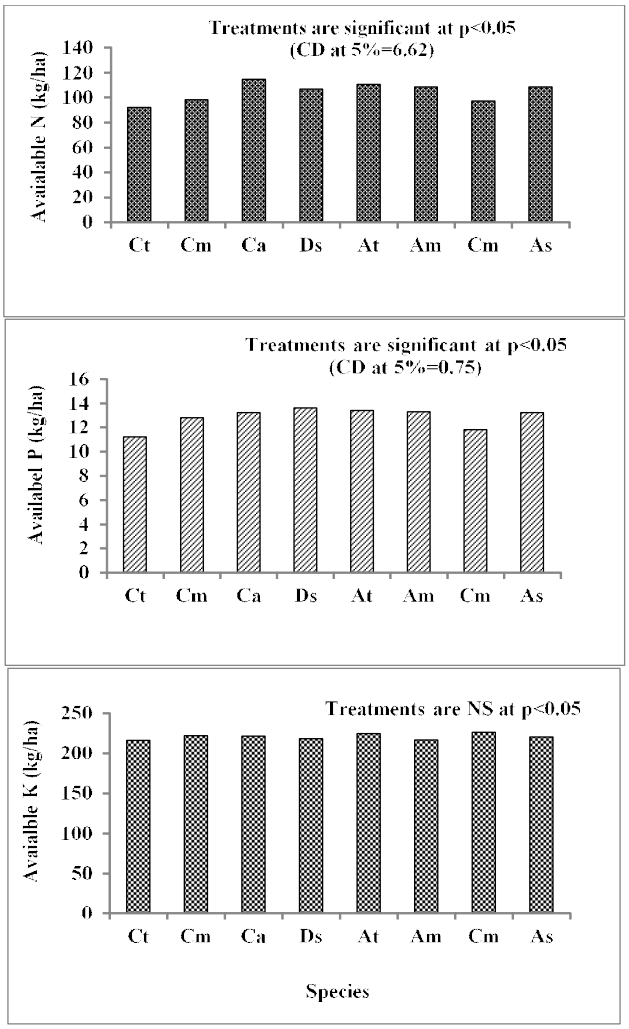

Fig 1: Average N, P and K content of soil (After 2 years) after harvest of mustard incorporated with different leaf litters (Ct-Control, Cm=*Colophospermum mopane, Ca=Citrus aurontifolia, Ds=Dalbergia sissoo, At= Acacia tortilis, Am=Aegle marmelos, Co=Cordia myxa, As=Acacia senegal*).

Soil nutrient status after crop harvest

Concentration of available N and P after the crop harvest was significantly more in litter amended soils as compared to control (Table 7, Fig 1). No significant difference was observed in available K in litter amended soils as compared to control. The concentration of available N was maximum in *Citrus aurontifolia* amended soil and followed the order *Citrus aurontifolia* > *Acacia tortilis*>*Aegle marmelos*> *Acacia senegal* > *Dalbergia sissoo.* This was due to higher nitrogen content in the leaf litters of *Citrus aurontifolia* (2.17%), *Acacia tortilis* (2.18%), *Acacia senegal* (1.76%), *Aegle marmelos* (1.66%) and *Dalbergia sissoo* (1.51%) as compared to *Colophospermum mopane* (0.99%) and *Cordia myxa* (0.93%). This shows that the addition of leaf litters with higher nutrients *viz*. N and P to the poor fertility soils enhance the available N and P in soil which have been reported by other authors also (Murthi *et al.,* 1990). Murthy *et al.* (1990) found that the incorporation of siris (Albizia lebbeck) (4.7% N), neem (2.6% N) and subabul (3.2% N) leaves improved the available and total N status of soil over control (no incorporation). Singh and Sharma (2007) found that the soils amended with leaf litter of dek (1.42% N) had significantly higher soil available nutrient as compared to poplar (1.26% N) and eucalyptus (1.04% N) leaf litters.

CONCLUSION

It may be concluded that the application of leaf litters of *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* can increase the grain and straw yield of moth bean and mustard as compared to the litters of other species. The average increase in grain yield was 14-16 percent by the leaf litters of these species. The uptake of nutrients was also improved in *Citrus aurontifolia*, *Aegle marmelos* and *Dalbergia sissoo* amended litters. It was found that the higher uptake of nutrients in *Citrus aurontifolia*, *Aegle marmelos and Dalbergia sissoo* litter amended soils was due to their better quality leaf litters in terms of low C:N ratio and low lignin content which enhance the rate of litter decomposition, faster release of nutrients and higher yield. However, the role of suitable micro-organisms towards faster decomposition of leaf litters may be explored in future for slow decomposing litters *viz*. *Colophospermum mopane* and *Cordia myxa*.

ACKNOWLEDGEMENT

The authors are highly thankful to Director, ICAR-CAZRI, Jodhpur for providing necessary facilities and suggestions during the course of this study.

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