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# Productivity and Growth Indices of Intercrops in Agri-Horti-Silvi System in Arid Rajasthan

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**Abstract:** Mung bean (*Vigna radiata* (L.) R. Wilczek) and clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) were grown as inter crops under agri-horti-silvi system with 9-year-old plantations of citrus (*Citrus aurontifolia*), mopane (*Colophospermum mopane*) and shisham (*Dalbergia sissoo*) at Research Farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner, during kharif 2011. Highest total biological yield and seed yield of mung bean (1412.5 and 471.3 kg $ha^{-1}$, respectively) and clusterbean (1352 and 419.8 kg $ha^{-1}$, respectively) was recorded in intercropping with citrus. Highest leaf area $plant^{-1}$ and chlorophyll content in clusterbean (2.44 mg $g^{-1}$ FW) and mung bean (2.62 mg $g^{-1}$ FW) intercropped with citrus were responsible for more seed yield due to accumulation of more photosynthates in plants. Higher leaf water potential of clusterbean (-3.18 MPa) and mung bean (-3.28 MPa) was recorded in intercropping with mopane. Among different tree leaves, leaf water potential was highest in mopane (-6.99 MPa) followed by citrus (-5.51 MPa) and shisham (-3.58 MPa).

**Key words:** Agri-horti-silvi system**,** arid, clusterbean, mung bean, productivity.

The climatic conditions of arid Rajasthan are not very conducive to agricultural production especially during kharif season due to occurrence of frequent droughts. Thus the farmers go only for one season cropping due to lack of irrigation facilities. Now with the commencement of Indira Gandhi Nahar Paryojna (IGNP) and development of tube wells, efforts are being made to develop arid lands through agri-horti, agri-silvi and agri-pasture systems. Researchers have shown that growing location-specific crop in combination with tree/grasses not only mitigate the risk of total crop failure, but can also increase resource use efficiency and replenish soil fertility (Soni *et al.*, 2007).

The success of any system will depend upon the competitiveness of trees and crops when grown together. The common hypothesis which restricts to combine the trees and crops together is that the tree production is realized only at the expense of crop growth (Cannell, 1996). If the trees deprive the crop of shared resources in limited supply, crop production in agroforestry will be impaired (Anderson and Sinclair, 1993). It is therefore critical for the success of agroforestry that competition for resources between trees and crops is avoided, or at least minimized.

Hence, a major challenge for management of agroforestry is to control competition and encourage 'complementarity' between trees and crops. Complementarity occurs when components of mixed vegetation utilize spatially or temporally distinct sources and consequently avoid competition (Anderson and Sinclair, 1993). If trees are more deep rooted than crops, and seasonal rainfall is sufficient to cause infiltration beyond the crop rooting zone, trees are able to utilize water that would otherwise have been lost as drainage. The complementarity in use of below ground resources is achieved by utilizing tree species with deep root systems that have few superficial lateral roots. Such ideal trees would show spatial complementarity with crops in use of below ground resources. Studies on intercropping of the horticultural trees with annual crops has been carried out (Reddy *et al.,* 1992; Reddy and Willey, 1981). However, no information is, available on suitability of intercrop which can be grown in association with citrus, mopane and shisham in arid region. The present experiment was therefore, conducted to study the suitability of intercrops in agri-horti-sivi systems of citrus, mopane and shisham under sprinkler irrigation.

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## Materials and Methods

The present investigation was carried out at the Research Farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner (latitude 28.03°N, longitude 73.19°E), and India during kharif 2011. The total rainfall during the year 2011 was 415.1 mm (Jan-Dec), which was 62.74% higher than normal average rainfall (255 mm). During the cropping season (July-October) the total rainfall was 365 mm. The soils of the experimental site was alkaline (pH=8.3), non-saline ($EC_2$=0.22 dS $m^{-1}$), loamy sand with low organic carbon (1.0 g $kg^{-1}$), available N (82 kg $ha^{-1}$), available P (9.2 kg $ha^{-1}$) and available K (205 kg $ha^{-1}$) and can store moisture 112 mm $m^{-1}$ soil profile. The mung bean [*Vigna radiata (*L.)] and clusterbean [*Cyamopsis tetragonoloba* (L.)] were intercropped during kharif season with 9-year-old citrus (*Citrus aurontifolia*), mopane (*Colophospermum mopane*) and shisham (*Dalbergia sissoo*) plantation under sprinkler irrigation system. Recommended agronomic practices and plant protection measures were followed for individual crops and trees. The trees viz. citrus, mopane and shisham were planted at 6 m x 5 m distance in which the intercrops were grown in the tree row spacing of 6 m. Fertilizers were applied as per the recommendations of tree species and inter crops. Growth data of fruit and silviculture trees were recorded in month of November. After November, the trees become dormant and growth of plants is checked due to winter season. Relative water content (RWC) of leaf was estimated by using the following relationships given by Gao (2000).

RWC (%) = [(Fresh weight - Dry weight)/ (Turgid weight – Dry weight)] x 100

Leaf water potential of the youngest, fully expanded leaves was measured at 9.30-11.30 AM by using WP4 Dew-point Potential Meter. Chlorophyll was extracted by the non-maceration method (Hiscox and Israelstam, 1979). Leaf samples (0.05 g) were incubated in 10 ml of dimethyl sulfoxide (DMSO) at 65°C for 4 hr absorbance were recorded at 645 and 663 n.m. and chlorophyll a, b, and total chlorophyll were estimated according to Arnon (1949).

The intercrops i.e. mung bean (variety K-851) and clusterbean (variety RGC-936) were sown in the month of July, 2011 with recommended dose of fertilizer (20:40 N:P kg $ha^{-1}$). The treatment of sole trees (without intercropping) was also taken separately for comparison. Irrigation was applied through sprinkler system (6 irrigations) as and when required. All the treatments were tested under randomized block design with three replications.

## Results and Discussion

### *Growth of trees*

The data presented in Table 1 showed that highest plant height of citrus and mopane was recorded with intercropping of clusterbean, whereas shisham attained maximum height with intercropping of mung bean. All the trees in intercropping system showed significantly higher plant height over no intercropping. The increase in height of citrus, mopane and shisham in intercropping system was 15.38, 9.50 and 11.67% higher over their sole planting, respectively. Intercropping of mung bean increased the stem girth by 45.24 and 18.18% and canopy by 39.48 and 19.54% in citrus and mopane, respectively, over sole planting. The effect of both the intercrops on growth of trees was at par with each other.

### *Performance of intercrops*

Mung bean and clusterbean intercropped with citrus showed highest plant height, number of branches $plant^{-1}$ and number of pods $plant^{-1}$ followed by shisham and mopane. Highest total biological yield of mung bean (1412.5 kg $ha^{-1}$) and clusterbean (1352.0 kg $ha^{-1}$) was also recorded in intercropping with citrus, which was 9.70 and 172.5% higher in mung bean and 21.31 and 161.3% higher in clusterbean over intercropping with shisham and mopane, respectively (Table 2). This was because of less competition for moisture and nutrients of citrus trees with the intercrops in comparison to shisham and mopane. Increased yield of cucumber fruit and minimal interference in the growth of citrus seedlings was also reported by Natarajaa and Nairk (1992).

The same trend was observed in seed yield of both the intercrops. Highest seed yield of mung bean (471.3 kg $ha^{-1}$) and clusterbean (419.8 kg $ha^{-1}$) was recorded with citrus, which was 50.8, 84.8 and 54.2, 184.0% higher over intercropping

*Table 1. Growth of trees as affected by different intercrops in agri-horti-silvi system*

| Trees | Mung bean | Clusterbean | Sole tree | Mean |
|---|---|---|---|---|
| Plant height (cm) | | | | |
| Citrus | 281.67 | 300.00 | 260.00 | 277.08 |
| Mopane | 380.00 | 402.33 | 367.00 | 383.17 |
| Shisham | 590.00 | 578.33 | 528.33 | 573.33 |
| Mean | 417.22 | 426.89 | 385.11 | |
| CD (0.05) | T=18.52 | C=21.39 | | |
| Stem girth (cm) | | | | |
| Citrus | 46.00 | 45.00 | 31.67 | 40.83 |
| Mopane | 78.00 | 74.33 | 66.00 | 71.25 |
| Shisham | 59.00 | 65.67 | 45.67 | 56 |
| Mean | 61.00 | 61.67 | 47.78 | |
| CD (0.05) | T=4.33 | C=4.99 | | |
| Tree canopy ($m^2$) | | | | |
| Citrus | 13.67 | 13.46 | 9.80 | 12.53 |
| Mopane | 25.10 | 24.53 | 21.00 | 23.35 |
| Shisham | 15.33 | 18.76 | 16.20 | 17.15 |
| Mean | 18.06 | 18.92 | 15.67 | |
| CD (0.05) | T=2.46 | C=2.84 | | |

with shisham and mopane, respectively. Thus, mopane and shisham showed more competitive effect on intercrops than citrus. Dwivedi *et al.* (2007) have also reported the maximum wheat yield under citrus plantation followed by aonla and minimum crop yield was recorded under guava plantation. This may be attributed to reduce tillering on account of shade effect.

*Leaf chlorophyll content in trees and crops*

The mopane and shisham adversely affected the total chlorophyll content in intercrops on fresh weight (FW) basis. The highest chlorophyll content in clusterbean (2.44 mg $g^{-1}$ FW) and mung bean (2.62 mg $g^{-1}$ FW) and chlorophyll a/b ratio was recorded in intercropping with citrus and lowest in intercropping with mopane (Table 3). This may be due to the shade effect of mopane because of its dense canopy as compared to citrus. Among different trees the total chlorophyll content was highest in mopane (2.69 mg $g^{-1}$ FW) followed by shisham (2.31 mg $g^{-1}$ FW) and lowest in citrus (1.58 mg $g^{-1}$ FW). The chlorophyll a/b ratio in all the trees was found to be non-significant.

*Table 2. Growth and yield of intercrops with trees under agri-horti-silvi system*

| Trees | Plant height (cm) | No branches $plant^{-1}$ | No. pods $plant^{-1}$ | Total biological yield (kg $ha^{-1}$) | Seed yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|
| Mung bean | | | | | |
| Citrus | 57.50 | 3.00 | 47.50 | 1412.50 | 471.30 |
| Mopane | 34.75 | 1.00 | 10.50 | 775.00 | 255.00 |
| Shisham | 55.25 | 2.50 | 22.75 | 1287.50 | 312.50 |
| Mean | 49.17 | 2.16 | 26.91 | 1158.33 | 346.25 |
| CD (0.05) | 10.03 | 1.00 | 2.29 | 331.62 | 116.47 |
| Clusterbean | | | | | |
| Citrus | 42.50 | 3.25 | 16.25 | 1352.00 | 419.80 |
| Mopane | 38.50 | 1.50 | 14.00 | 517.30 | 147.80 |
| Shisham | 54.00 | 3.00 | 25.50 | 1114.50 | 271.50 |
| Mean | 45.00 | 2.58 | 18.53 | 994.58 | 279.75 |
| CD (0.05) | NS | NS | NS | 244.30 | 58.29 |

*Table 3. Chlorophyll content (mg $g^{-1}$ FW) in trees and intercrops under agri-horti-silvi system*

| Trees | Chlorophyll content (mg $g^{-1}$ FW) | | | |
|---|---|---|---|---|
| | Chlorophyll a | Chlorophyll b | Total Chlorophyll | Chlorophyll a/b ratio |
| Clusterbean | | | | |
| Citrus | 1.47 | 0.98 | 2.44 | 1.50 |
| Mopane | 1.27 | 0.92 | 2.19 | 1.38 |
| Shisham | 1.34 | 0.95 | 2.29 | 1.42 |
| Mean | 1.35 | 0.95 | 2.31 | 1.43 |
| Mung bean | | | | |
| Citrus | 1.62 | 1.01 | 2.62 | 1.76 |
| Mopane | 1.24 | 0.88 | 2.12 | 1.41 |
| Shisham | 1.46 | 1.09 | 2.55 | 1.34 |
| Mean | 1.44 | 0.99 | 2.43 | 1.50 |
| Sole trees | | | | |
| Citrus | 0.87 | 0.71 | 1.58 | 1.26 |
| Mopane | 1.52 | 1.17 | 2.69 | 1.30 |
| Shisham | 1.29 | 1.02 | 2.31 | 1.27 |
| Mean | 1.23 | 0.97 | 2.19 | 1.27 |
| CD ( 0.05) | | | | |
| Trees | 0.095 | 0.134 | 0.212 | 0.221 |
| Crops | 0.095 | 0.134 | 0.212 | 0.221 |
| Tree x crops | 0.164 | 0.231 | 0.366 | 0.382 |

## *Leaf area of intercrops*

Significantly lower leaf area of clusterbean and mung bean was recorded in intercropping with mopane as compared to citrus and shisham (Table 4). The highest leaf area plant$^{-1}$ of mung bean (558.5 $cm^2$ plant$^{-1}$) was recorded in intercropping with citrus which was 150.9% higher over intercropping with mopane, but was found to be at par in intercropping with shisham. In clusterbean, the highest leaf area was recorded in intercropping with shisham (441.9 $cm^2$ plant$^{-1}$) followed by citrus (381.8 $cm^2$ plant$^{-1}$), but the difference was non-significant.

*Table 4. Leaf area ($cm^2$ plant$^{-1}$) of intercrops as influenced by trees under agri-horti-silvi system*

| Trees | Leaf area ($cm^2$ plant$^{-1}$) | |
|---|---|---|
| | Mung bean | Clusterbean |
| Citrus | 558.8 | 381.8 |
| Mopane | 222.7 | 222.8 |
| Shisham | 554.3 | 441.9 |
| Mean | 445.3 | 348.8 |
| CD (0.05) | 110.6 | 90.31 |

## *Leaf water potential*

The higher leaf water potential in clusterbean (-3.18 MPa) and mung bean (-3.28 MPa) was recorded in intercropping with mopane which was 18.65, 24.22 and 41.40, 62.94% higher over their intercropping with shisham and citrus, respectively (Table 5). Among different trees (month of November) more negative leaf

*Table 5. Leaf water potential (-MPa) in crops and sole trees under agri-horti-silvi system*

| Trees | Intercrops | | | |
|---|---|---|---|---|
| | Clusterbean | Mung bean | Sole tree | Mean |
| Citrus | -2.48 | -1.97 | -5.51 | -3.32 |
| Mopane | -3.18 | -3.21 | -6.99 | -4.46 |
| Shisham | -2.68 | -2.27 | -3.58 | -2.84 |
| Mean | -2.78 | -2.48 | -5.36 | |
| CD (0.05) | Trees and crops=0.639 | | Tree x crops=1.106 | |

water potential was observed with mopane (-6.99 MPa) followed by citrus (-5.51 MPa) and shisham (-3.58 MPa). The more negative leaf water potential of mopane was due to higher soil moisture extraction by its surface feeding roots (0-30 cm) and thus creating more stress to the intercrops. Beniwal *et al.* (2007) reported that the total soil moisture depletion from the profile was maximum in mopane followed by shisham and citrus. The extensive root system of mopane resulted in higher soil moisture extraction from cropping zone as compared to citrus and shisham. They further reported that the root biomass density of mopane at a radial distance of 1.0-2.5 meter was more (134.8 g $m^{-3}$) as compared to shisham (74.7 g $m^{-3}$) and citrus (16.7 g $m^{-3}$). The fibrous and thin roots of mopane were 2.4 and 16.3 times more than citrus in 1.0-2.5 m lateral distance from the trees, which compete with intercrops for moisture (Beniwal *et al.*, 2007). Since root biomass and soil moisture extraction by citrus in cropping zone (i.e. 2.5 m radial distance) was less, it can perform well in agri-horti system with minimum effect on crop growth and yield.

The study revealed that intercropping of clusterbean and mung bean in agri-horti system can successfully be done through sprinkler irrigation in 9-year-old citrus plantations without any reduction in productivity of intercrops as well as the growth of citrus trees. In agri-silvi system the mopane proved as the most competitor tree especially for moisture due to higher leaf water potential than shisham resulting in poor intercrop growth and yield due to more competition for moisture and therefore some cultural intervention like root pruning, trenching along the tree rows etc. may help for good growth and yields of intercrop with mopane. Growth of all the trees was better with intercropping than the sole trees (without intercropping) which showed that intercropping have positive effect on growth of trees in agri-hort-silvi system under irrigated arid condition of Rajasthan.

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