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Development of Climate Resilient Agri-Silvi-Horticultural System for South West Haryana

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A B S T R A C T

A field experiment was conducted in an already established Agri-silvi-horticultural system of agro-forestry at CCS H.A.U. Regional Research Station, Bawal (Rewari) during both *Kharif* and *Rabi* seasons of 2019-20, in which, Mahaneem (*Ailanthus excelsa*) was taken as forest tree species and Guava (*Psidium guajava*) and Aonla (*Embilica officinalis*) as horticulture trees planted at 6×6 m distance. In *Kharif* season, fodder crops i.e. Cowpea (*Vigna ungiculata*), Bajri (*Pennisetum glaucum*) and Dhaincha (*Sesbania aculeata*) were taken in association with perennial woody plants forming agri-silvi-horticultural system of agroforestry. While in *Rabi* season, fodder crops i.e. Oat (*Avena sativa*), Kasni (*Chicorium intybus*) and Barley (*Hordium vulgare*) were taken. Green fodder yield of all fodder crops was recorded during both the seasons and under both agri- silvi-horticulture system and sole crops. Among the agri-silvi-horticulture systems, Kasni + Guava + Mahaneem exhibited the highest yield. Maximum green fodder yield was received by Bajri + Guava + Mahaneem based agri-silvi-horticulture system during *Kharif* season while in *Rabi* season Kasni + guava + Mahaneem based agri-silvi-horticulture system attained highest yield followed by Kasni + Aonla + Mahaneem based agri-silvi-horticulture system. Similarly the total green fodder yield was found maximum in Kasni sole (537.97 q/ha) followed by oat sole (487.80q/ha) and barley sole (392.25 q/ha) during *Rabi* season while in *Kharif* season maximum green fodder yield was attained by bajri sole (190.71 q/ha) followed by Dhaincha sole (129.26q/ha) and cowpea sole (109.66 q/ha). Same trend was observed under Aonla+ Mahaneem based agri-silvi-horticulture system. The green fodder yield was found significantly higher under control (sole cropping) and among the various agri-silvi-horticulture systems, Guava + Mahaneem system recorded higher yield than Aonla + Mahaneem system. *Rabi* season fodder crops attained higher yield as compared to *Kharif* season fodder crops.

Introduction

The fast agricultural development in the Haryana has deteriorated the agro-ecosystem through excessive use of natural resources. Heavy depletion of soil health, lowering of water table and high rate of environmental pollution are the matters of great concern for the future of the state (Aulakh, 2005; Bambi and Brar, 2009). The short supply of food, fiber, fodder and fuelwood has made the situation more critical. Low and erratic rainfall, poor fertility and high solar radiation have made the agriculture a risky busiss in arid and semiarid regions Kaushik *et al.*, 2017.

It has been estimated that an increasing population and changing dietary intake will lead to about 80–120% increase in global

food requirement by 2050 (Tilman *et al.*, 2001; FAO 2006; Foley *et al.*, 2012). However, the ever-increasing human and livestock population and developmental activities exert enormous pressure on the slender natural resource base of the region. Agroforestry has been identified as the most appropriate land use option having both ecological and economic interactions. It is considered as a panacea for maladies of intensive agriculture (Pingali, 1999). Planting of trees by the farmers on their fields to meet their basic needs of food, fodder and fuelwood is common in these areas. Improved agroforestry systems (agri–silvi–horti) in arid and semiarid areas can meet the timber requirement of industry with basic needs of the farmers. Adoption of horticultural plants has special significance in arid regions, particularly in drought prone areas because these indigenous plants once established become perennial source of income imparting stability as well. (Bhandari et. al., 2014). Moreover, the region is bestowed with drought hardy horticultural plants like Bengal quince (*Aegle marmelos*), Indian cherry (*Cordia myxa*), Indian gooseberry (*Emblica officinalis*), Indian jujube (*Ziziphus mauritiana*), Jharber (*Z. nummularia*), Pilu (*Salvadora oleoides*) and many other multi-purpose species.

According to 2012 census, India carries a huge livestock population of 512.05 million consisting of cattle, buffalo, sheep, goat, horses and ponies, *etc.* (Ranjan *et al.*, 2016). United States Department of Agriculture (USDA), 2016 also reported that India has the largest cattle inventory in the world followed by Brazil and China which accounts for approximately 31% of total cattle. The availability of green and nutritious fodder plays a very crucial role in dairy management and supplementing the sustainable productivity of milk which is a major source of nutrition for the majority of the human population. Inadequate and seasonal production of fodder creates an acute shortage of livestock feeds and fodders hence, forming a large gap between needs and availability, which is the major challenge to overcome the quality and quantity of the fodders (Ranjan *et al.*, 2016). Therefore, intercropping of legumes and fodder crops underneath trees is a promising theme for increasing and stabilizing yields in silvi-pastoral system for its potential for increasing and stabilizing yields, reducing grazing pressure, sustaining tree health and increasing self-sufficiency with fodder (Ranjan *et al.*, 2016).

Forage and feeds are the major inputs in animal husbandry, which constitute nearly 70 % of the total cost of production. Therefore, there is a high need to augment high-quality fodder production adopting significant varieties and improved crop management practices of cultivated fodders including dual-purpose crops, pasture improvement, adopting technological interventions and plantation of woody perennials to establish live fodder bank (Sharma, 2013). The traditional animal husbandry based cropping systems practiced in these regions has multi species character wherein millets, pulses and oil seed crops are planted in fields along with multipurpose trees and shrubs. The leaves of these species are lopped and fed to the livestock during the lean period (Bhandari et. al., 2014).

Adoption of these alternative production systems has also enhanced the availability of fodder for livestock, improved the quality of produce for the desert inhabitants, optimized the utilization of land and water resources, enriched the soil fertility, generated additional employment for the inhabitants improving their overall socio-economic status and in preventing the migration. (Bhandari et. al., 2014). Reduction in yield of arable crops under agroforestry in the tropics and subtropics is well known, but information on

how different agroforestry systems influence the yield of crops is scanty. All types of agroforestry models may not be useful for all sites, but the old and traditional practices can be manipulated for meeting site-specific needs. Therefore, various agroforestry models (agri–silvi–horti systems) were developed to study their performance under semiarid conditions in north-west India.

Materials and Methods

Experimental site

The study was carried out at Chaudhary Charan Singh Haryana Agricultural University Regional Research Station, Bawal (28.1°N, 76.5°E at 266 m MSL), Haryana, India. During experimentation period, the maximum temperature reached as high as 41 °C during July and April whereas, during peak winter months of December and January, the minimum temperature was recorded around 1 °C and 0.6 °C, respectively.

The site is characterized by low (350–550 mm) and erratic rainfall during monsoon (July–September). The winter (October–March) remains almost dry. Evapotranspiration rate of 5.3 mm/day was observed during rainy (July–October) and 2.7 mm/day during winter season (November–February). The soil of the experimental site was sandy loam in texture, low in organic carbon (0.18%), medium in available phosphorus and available potassium.

Experimental details

The present study was carried out on 19 years old already established two horticultural fruit tree species, *i.e.*, guava (*Psidium guajava*) and *Aonla* (*Embilica officinalis*) based agri-silvi-horticultural system of agro-forestry at Bawl, in which, Mahaneem was grown 2013 in between the interspaces of fruit tree species. The perennial woody plants were planted at a distance of 6×6 m from row to row and plant to plant, respectively. Third components of the system, *i.e.*, agricultural crops which includes both *Kharif* (Cowpea (*Vigna ungiculata* cv.Pant-1), Bajri (*Pennisetum glaucum* cv. local) and Dhaincha (*Sesbania aculata* cv. local)) and *Rabi* season (Oat (Avena sativa cv. HJ-7), Kasni (*Chicorium intybus* cv. local) and Barley (*Hordeum vulgare* cv. BH-393)) fodder crops were taken in association with perennial woody plants, thus forming agri-silvi-horticultural system of agro-forestry. The fodder crops rotation which was followed during experimentation was as:

1. Dhaincha followed by Barley
2. Bajri followed by Kasni
3. Cowpea followed by Oat

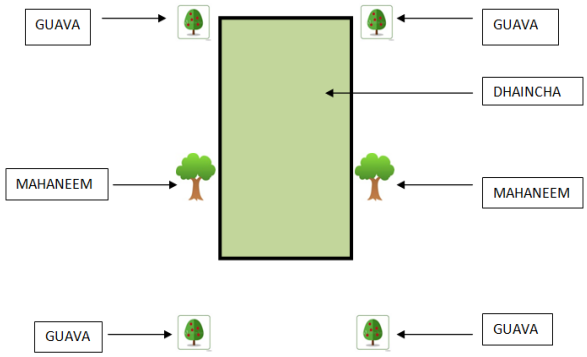
The plantation of guava and aonla was carried out in July 2000 and plantation of mahaneem in July 2013. The trees were raised in rows in East- West direction. The rows of fruit trees Guava + Aonla were followed by mahaneem rows. In a single row of fruit trees raised in east west direction comprises of 1st three trees of guava followed by six trees of aonla than again three trees of guava at the end of the row thus a single row of fruit trees comprises of total six trees of guava and six trees of aonla and having a plant to plant spacing of 6 meters.

The fruit tree row was followed by row of mahaneem in northern direction at a distance of 6 m and having total 12 trees of mahaneem in a single row then mahaneem row was followed by fruit tree row. On the corner of each plot were fruit trees while in the middle of 12 m length was mahaneem trees. The crops raised were for fodder purpose and total yield of green fodder of each crop was recorded for each and every treatment with

three replications for each treatment. The *Kharif* crops were harvested in a single cutting after 50 days of sowing. The *Rabi* crops were harvested in two cuttings 1st cutting after 65 days of sowing and 2nd cutting after 40 days of 1st cutting. The total yield comprises of both the cuttings for each *Rabi* season crop.

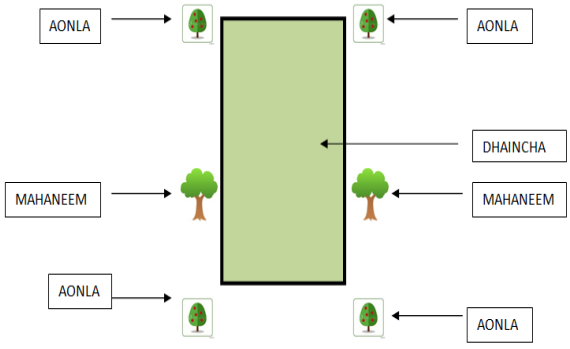
Treatment-1

Dhaincha in *Kharif* in the plot with guava at corners + mahaneem in the middle



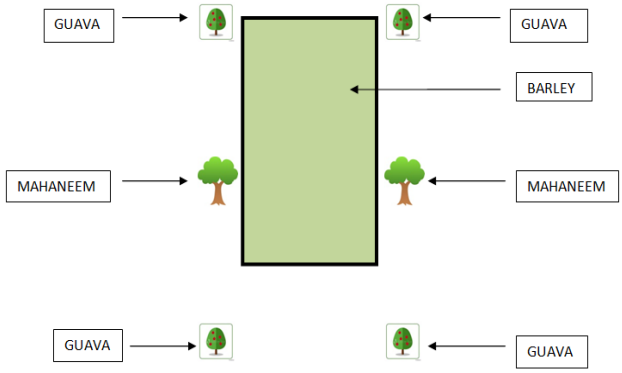
Treatment-2

Dhaincha in *Kharif* with the plot having aonla at corners + mahaneem in the middle



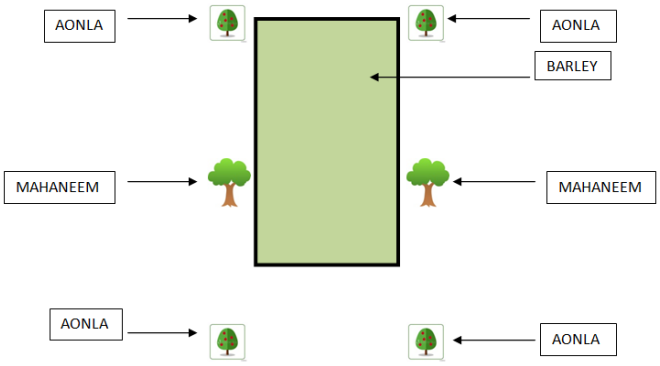
Treatment-3

Barley in *Rabi* season in the plot with guava at corners + mahaneem in the middle



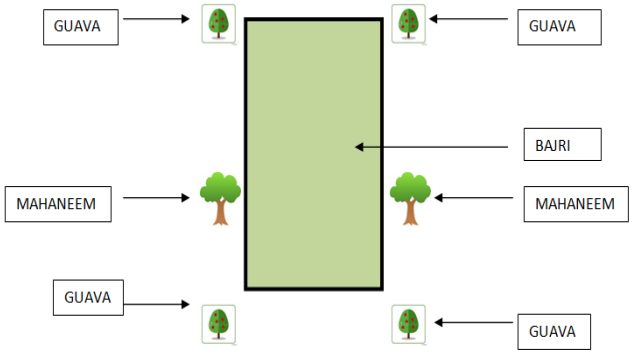
Treatment-4

Barley in *Rabi* season with the plot having Aonla at corners + mahaneem in the middle



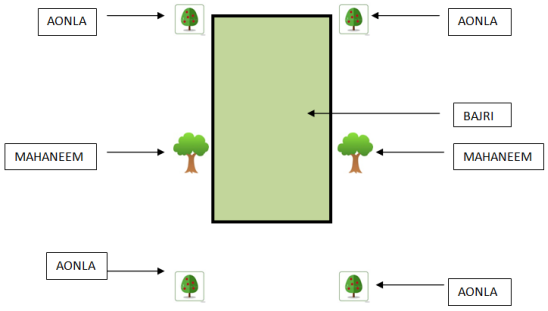
Treatment-5

Bajri in *Kharif* season in the plot with guava at corners + mahaneem in the middle



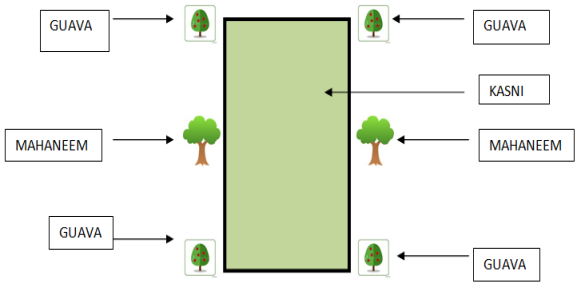
Treatment-6

Bajri in *Kharif* with the plot having aonla at corners + mahaneem in the middle



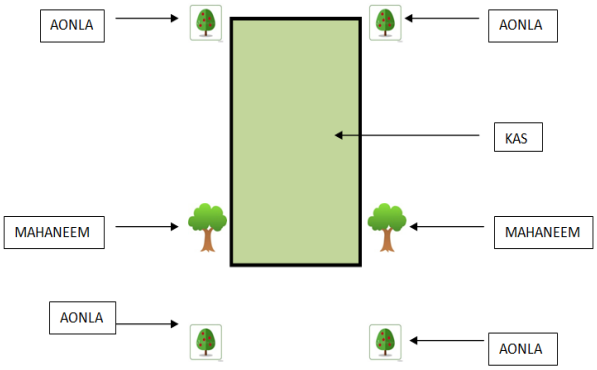
Treatment-7

Kasni in *Rabi* season in the plot with guava at corners + mahaneem in the middle



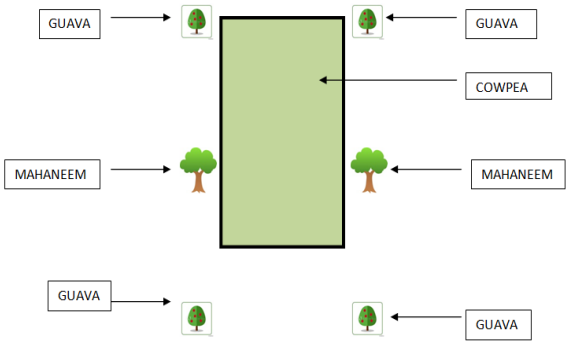
Treatment-8

Kasni in *Rabi* season with the plot having aonla at corners + mahaneem in the middle



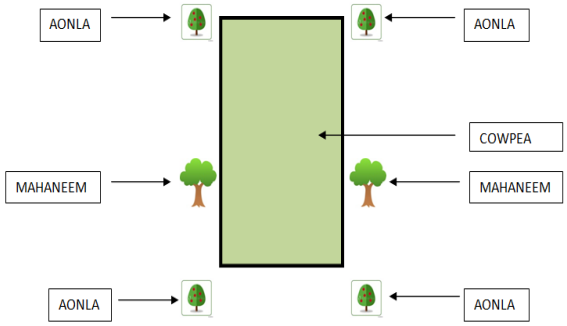
Treatment-9

Cowpea in *Kharif* season in the plot with guava at corners + mahaneem in the middle



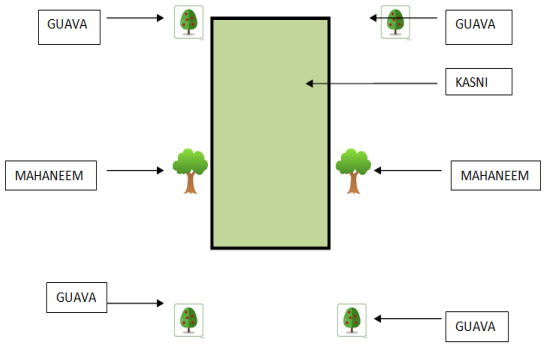
Treatment-10

Cowpea in *Kharif* with the plot having aonla at corners + mahaneem in the middle



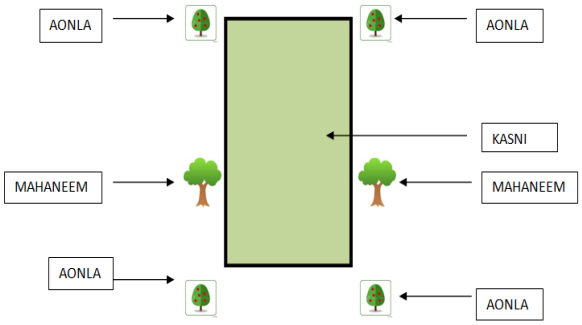
Treatment-11

Oat in *Rabi* season in the plot with guava at corners + mahaneem in the middle



Treatment-12

Oat in *Rabi* season with the plot having aonla at corners + mahaneem in the middle



1. Treatment-13 Sole Dhaincha (without trees)
2. Treatment-14 Sole Bajri (without trees)
3. Treatment-15 Sole Cowpea (without trees)
4. Treatment-16 Sole Barley (without trees)
5. Treatment-17 Sole Kasni (without trees)
6. Treatment-18 Sole Oat (without trees)

The data for green fodder yields under both under agri-silvi-horticultural system and sole cropping was recorded for 2019-20. The various indices estimated in the study are given as under:-

Fresh fodder yield (t ha^{-1})

All plants of fodder crop were harvested from each plot in four replications, bundled and labeled. Bundles of each plot were then weighed to record the green fodder yield and converted into ton per hectare.

Statistical analysis of data

The data obtained during this investigation were analyzed statistically as per method given by Panse and Sukhatme (1989).

Critical difference

Critical difference for all the characters was calculated to compare the treatment means. Critical differences were calculated with the help of standard error for the difference of two means and multiplied by the tabulated value of 't' at 5 percent level of significance for error degree of freedom;

CD = S.Ed. x t at 5% error of d.f.

Results and Discussion

Green fodder yield of fodder crops

Green fodder yield (q/ha) of all fodder crops taken as sole crop were significantly higher than yield under agri-silvi-horticulture system (Table-2). Among all *Kharif* fodder crops taken during experimentation sole Bajri crop (190.71 q/ha) was having significantly higher yield while among *Rabi* fodder crops sole Kasni crop (537.97 q/ha) was having highest green fodder yield.

Among the agri-silvi-horticulture system, green fodder yield (280.68 q/ha) of Kasni in Guava + Mahaneem combination was significantly higher than other combination followed by Kasni + Aonla + Mahaneem (279.11 q/ha) during *Rabi* season. In *Kharif* season, among the agri-silvi-horticulture system, green fodder yield (30.20 q/ha) of Bajri in guava + Mahaneem combination was significantly higher than other combination followed by Bajri + Aonla + Mahaneem (13.74 q/ha).

Guava based combination (guava + Mahaneem) supported significantly higher green fodder yield of all fodder crops than *Aonla* based combination (aonla + Mahaneem) under agri-silvi-horticulture system and same trend was observed in all fodder crops.

Table.1 Rainfall and Temperature of experimental site during experimentation period

Months	Rainfall (mm)	Rainy days	Avg. maximum temperature (°C)	Avg. maximum temperature (°C)
Jul-19	150.9	13	34.09	27.45
Aug-19	115.8	12	33.71	25.82
Sep-19	165.2	8	33.12	24.56
Oct-19	9.2	2	33.57	18.54
Nov-19	5	1	27.91	13.82
Dec-19	13.9	1	17.56	8.61
Jan-20	8	4	18.82	5.5
Feb-20	1.4	1	23.63	7.70
Mar-20	68.8	7	27.48	12.01

Table.2 Green fodder yield (q/ha) of *Rabi* and *Kharif* crops under agri-silvi-horti systems

S. No.	Treatments (Kharif)	Yield (q/ha)	Treatments (Rabi)	Yield (q/ha)	Total *Kharif* &rabi
1	Dhaicha + Guava + Mahaneem	11.22	Barely + Guava + Mahaneem	121.17	132.39
2	Dhaicha + Aonla + Mahaneem	7.83	Barely + Aonla + Mahaneem	128.66	136.49
3	Bajri + Guava + Mahaneem	30.20	Kasni + Guava + Mahaneem	280.68	310.88
4	Bajri +Aonla + Mahaneem	13.74	Ksni +Aonla + Mahaneem	279.11	292.85
5	Cowpea + Guava +Mahaneem	9.28	Oat + Guava +Mahaneem	118.09	127.37
6	Cowpea + Aonla + Mahaneem	7.17	Oat+ Aonla + Mahaneem	108.67	115.84
7	Dhaincha sole	129.26	Barley sole	392.25	521.51
8	Bajri sole	190.71	Kasni sole	537.97	728.68
9	Cowpea sole	109.66	Oat sole	487.80	597.46
C.D.		3.54	C.D.	24.33	
SE(m)		1.21	SE(m)	8.29	
SE(d)		1.70	SE(d)	11.72	
C.V.		4.26	C.V.	6.08	

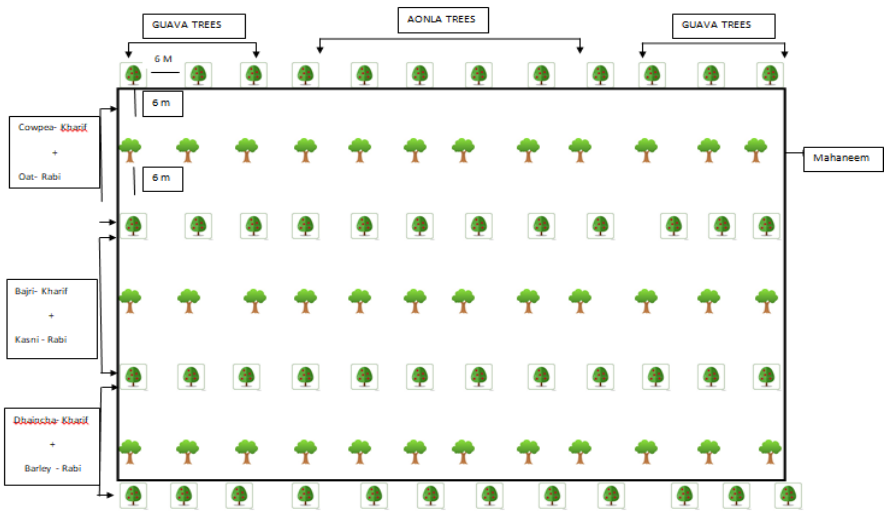
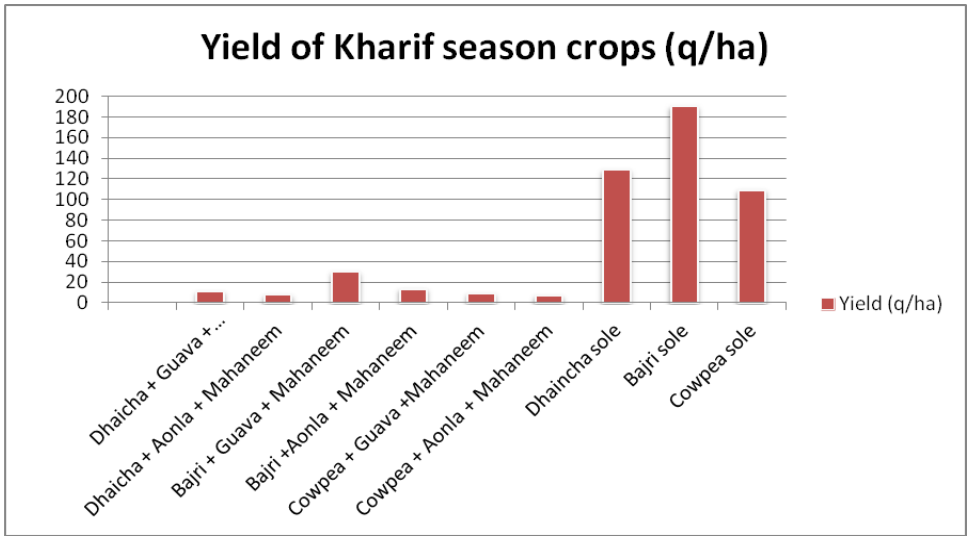
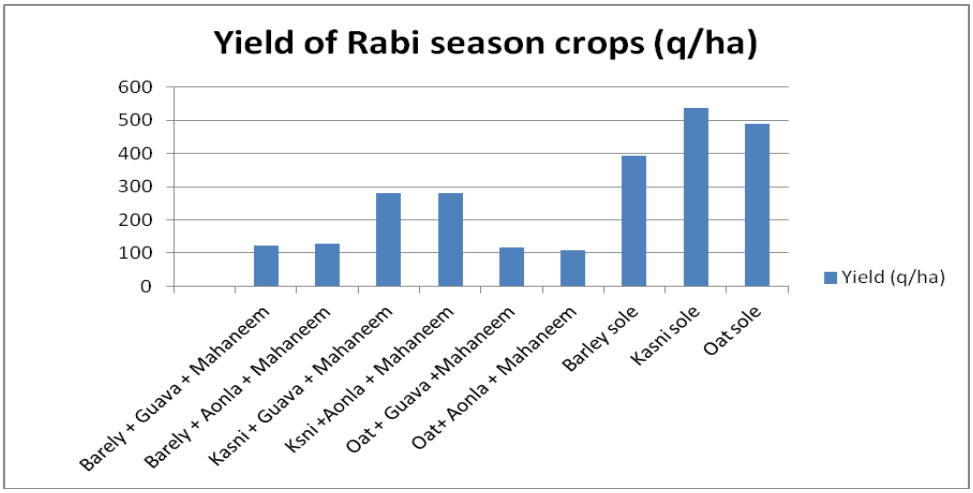

GUAVA TREES
AONLA TREES
GUAVA TREES
6 M
6 m
6 m
Cowpea- Kharif
+
Oat- Rabi
Mahaneem
Bajri- Kharif
+
Kasni - Rabi
Dhaincha- Kharif
+
Barley - Rabi

Fig.a


Yield of Kharif season crops (q/ha)
200
180
160
140
120
100
80
60
40
20
0
Dhaicha + Guava + ...
Dhaicha + Aonla + Mahaneem
Bajri + Guava + Mahaneem
Bajri +Aonla + Mahaneem
Cowpea + Guava +Mahaneem
Cowpea + Aonla + Mahaneem
Dhaincha sole
Bajri sole
Cowpea sole
Yield (q/ha)


Yield of Rabi season crops (q/ha)
600
500
400
300
200
100
0
Barely + Guava + Mahaneem
Barely + Aonla + Mahaneem
Kasni + Guava + Mahaneem
Ksni +Aonla + Mahaneem
Oat + Guava +Mahaneem
Oat+ Aonla + Mahaneem
Barley sole
Kasni sole
Oat sole
Yield (q/ha)

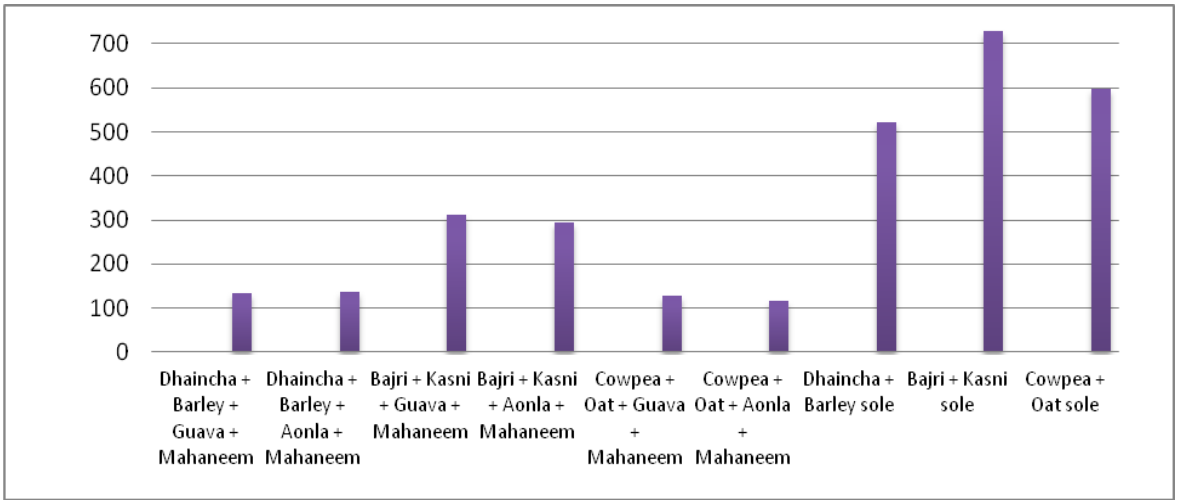


Figure.1 Total green fodder yield (qt/ha) from different cropping systems under mahaneem based agri- silvi- horticulture system

Among the cropping systems, Bajri - Kasni + guava + Mahaneem system attained highest (310.88qtl/ha) green fodder yield followed by Bajri - Kasni + aonla + Mahaneem system (292.85 q/ha), Dhaincha – barley + aonla + Mahaneem system (136.49 q/ha), Dhaincha – barley + guava + Mahaneem system (132.39 q/ha), Cowpea – oat + guava + Mahaneem system (127.37 q/ha) and Cowpea – oat + aonla + Mahaneem system (127.37 q/ha). While highest yield (728.68 q/ha) was attained by sole Bajri – Kasni cropping system.

Higher crop yield under mahaneem tree canopy due to improved soil fertility have been reported earlier by several workers (Maiti and Ghosh, 2020, Kaushik *et al*., 2017, Malti and Ahirwal, 2019). Kaushik et.al (2017) also observed that Mahaneem based agri-silvi system influenced the crop growth and grain yield positively in both *Kharif* and *Rabi* seasons. Green matter yield of dhaincha, grain yield of wheat and barley and fodder yield of berseem remained unaffected due to Melia azedarach during the first four years of plantation (Nandal and Kumar 2010). The average grain and straw yields of arable crops were more under sole cropping, but were statistically at par to those obtained from interspaces of various silvi-horticultural systems during initial four years of establishment (Kaushik *et al.*, 2011). Guava also had positive impacts on crops grown under its canopy.

Pateria *et al.*, (2005) observed the maximum productivity of wheat grown under guava might be due to the fact that guava improves water holding capacity of the soil and organic carbon stock in the soil (Jalalzai *et al.*, 2012). Singh *et al.*, (2008) reported that root secretion of guava pushed up the yield of intercrops over its sole cropping. The results are also corroborated with the findings of Khattak *et al.*, (1981) and Wannawong *et al.*, (1991). Malviya and Singh (1998) also reported that guava has some ameliorative effect on chemical properties of the soil. Based on experiment, it may be concluded that trees modified the microclimate and influenced diversity and productivity of canopy zone vegetation. The winter crops, *i.e.*, kasni, barley and oat should be grown with guava + *Mahaneem* combination under agri-silvi-horticulture system. It moderates the micro climatic condition of crop and makes it favourable for production of the crop.

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