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Research Article

DYNAMICS OF SOYBEAN YIELD AS UNDER STOREY CROP IN *D. SISSOO-E. OFFICINALIS*-BASED AGROFORESTRY SYSTEM

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Abstract: Agri-horti-Silviculture system of agroforestry caters the basic needs of food, fodder, fuel and timber for farmers in addition to its economic benefits. Among several combinations one of the suitable systems is with soybean, aonla and sissoo. A study was carried out to evaluate the performance of soybean as under storey crop with different proportion of tree combinations. Five treatments *viz.* 100% *Emblica officinalis*, 75% *Emblica officinalis* + 25% Dalbergia sissoo, 50% *Emblica officinalis* + 50% *Dalbergia sissoo*, 25% *Emblica officinalis* + 75% *Dalbergia sissoo* and 100% Dalbergia sissoo were selected for the study. Soybean production trend was evaluated continuously for three years from 2017 to 2019. One-year old trees were planted with desired combinations in all the treatments. Soybean variety NRC-86 was grown in all three years. In first year of 2017 (tree age was 2-year) soybean yield was at par in all the five treatments. In second year of 2018 (tree age was 3-year) soybean yield was significantly varying in few treatments. In third year of 2019 (tree age was 4-year) significant variation of soybean yield was recorded in almost all the treatments. In third year among the five selected treatments highest yield (1106 kg/ha) was recorded under 100%Emblicaofficinalis and lowest (841 kg/ha) under 100%Dalbergiasissoo. The mean soybean grain yield was declined from 1200 kg/ha to 846 kg/ha during 2017 to 2019. However, this reduction in yield may be compensated by tree component. Three-year study revealed that 75% *Emblica officinalis* + 25% *Dalbergia sissoo* with soybean is most suitable for farmers because it fulfils the basic needs of farmers.

Keywords: *Agri-hort-Silviculture, Agroforestry, Emblica officinalis, Dalbergia sissoo, Soybean*

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Introduction

Agroforestry is a poly-culture land use system. In this system one component of it competes with other component, for light, space and uptake of nutrients. Tree can affect under storey crop production positively through increased input of biomass from leaves and roots that often enhance nutrient cycling [1]. Agroforestry practices have positive relation with crop in terms of tree-crop water interaction [2] and adjacent crop climate [3]. However negative effect is also observed because of competition for light, nutrient and water. In agroforestry tree species, spacing and age also affect the crop production. In starting year of cultivation tree has less crown expansion & less developed root system which show very least or negligible impact on under storey crop. The quality and quantity of sun light play important role in under storey crop production starting from germination to harvesting which is regulated by tree component in agroforestry system. Any agroforestry system with more than 3-4year-old tree species as one of the major components may reduce the yield of crop due to canopy development [4,5]. Despite of this, species specific competition also plays important role in crop production. Different tree species with same age and same environment exhibit different type of competition and show variation in yield of under storey crop. The variation in beneath crop yield may be result of leaf architecture/crown shape, rooting pattern, symbiotic pattern and complexity of system. The architecture of leaves or shape of crown play important role in regulation of light intensity and interception of rain fall. The tree species having conical shape crown and phyllode type of branching pattern reduce tree-crop competition. The differences in yields under crowns of varying sizes and shapes indicate an effect of above ground competition between crops and tree component [6].

The decomposition rate of leaf material increased the rate of intake of nutrient like *Prosopis cinreria, Sesbenia* sp. *Gliricidia sepium etc.* may directly affect the yield of under storey crop. However, below ground competition also have same importance as above ground competition in multiple land use system. The types and formation of root contribute to below ground competition. In nature different type of tree species have different type of root producing ability like, shallow root system, suckers, deep tap root system *etc*. The tree species with deep rooted and to possess few lateral roots, suggests good potential for below-ground complementarity hence incorporated in agroforestry system of Steep Mountain slopes [7-9]. The complexity of system also has significant impact on crop yield as it competes for both space and light to other component of system. The shape, size, distances, orientation of species, architecture of root & leaf, growth behaviour and decomposition rate, all characters combined form or create micro-climate for agriculture crop. Hence an environment (micro-climate) created by tree component in agroforestry system play important role in regulation of crop yield. Several studies carried out across the globe reveal that agroforestry system of cultivation is eco-friendlier and more sustainable in nature compare to conventional agriculture or mono-cropping system. The present study aims to evaluate the impact of *Dalbergia sissoo* and *Emblica officinalis* tree component on yield of soybean crop in agroforestry system for different age of trees.

Material and Methods

The study was conducted in agroforestry unit of Krishi Vigyan Kendra (KVK), IGNTU, Amarkantak M. P. India. The study was carried out in Randomized Complete Block Design (RCBD) with five treatments and four replications.

One-year old Plants were planted with plant-to-plant distance of 4.5 meter and Row to Row distance of 5 meters. Sixteen plants were planted under each treatment in June 2016. Each plot was of 360 m^2. A bare strip of 2-meter-wide was maintained between each replication and treatment. Soybean crop variety NRC-86 was grown as under storey crop in all treatments during *Kharif* 2017, *Kharif* 2018 and *Kharif* 2019.

The treatments comprised, T1: 100% *Dalbergia sissoo* L. (all 16 plants of *D. sissoo*), T2: 75% *Emblica officinalis* Gaertn. + 25% *Dalbergia sissoo* L. (12 plants of E. officinalis & 4 plants of *D. sissoo*), T3: 25% *Emblica officinalis* Gaertn. + 75% *Dalbergia sissoo* L. (4 plants of E. officinalis & 12 plants of *D. sissoo*), T4: 50% *Emblica officinalis* Gaertn. + 50% *Dalbergia sissoo* L. (8 plants of *E. officinalis* & 8 plants of *D. sissoo*), and T5: 100% *Emblica officinalis* Gaertn. (All 16 plants of *E. officinalis*).

The crop was harvested after 120 days of sowing. Grain yield, straw yield and biomass yield were recorded by 1 m X 1 m crop cutting data. Five crop cutting data were recorded in each plot. The mean of these five data were considered for analysis. Equivalent grain yield was derived by considering the grain as well as straw yield of soybean. Govt. Minimum Support Price (MSP) of produce was considered for it. The straw yield of a treatment was converted into equivalent grain yield and added with the grain yield of that treatment to derive equivalent grain yield of that treatment. The MSP of soybean grain were considered as Rs 30.5, Rs 34.0 & Rs 37.1 per kg respectively for the year 2017, 2018 & 2019. The respective MSP for straw were considered as Rs 2.0, Rs 2.5 & Rs 3.0 per kg. All data were analysed in RCBD design.

Results

Performance of soybean grain, straw and Equivalent grain yield were analysed by preparing ANOVA for different years which is presented below.

Dynamics in the *Kharif* 2017

One-year old trees were planted in June 2016. The age of trees was two year at the time of sowing of soybean crop in the *Kharif* 2017. The analysed data of grain yield, straw yield, biomass yield and equivalent grain yield are presented in [Table-1]. The trends of all type of yield attributes of soya bean under each treatment in year 2017 has depicted in [Fig-1].

As evident from [Table-1], the grain yield of soybean is at par in different treatments. No significant difference in yield is observed between treatments. Similar trend is also observed in straw yield, biomass yield & equivalent grain yield in this year. It may be due to early age of trees. The overall mean yield in this year was 1200 kg/ha, 1806 kg/ha, 2535 kg/ha and 1319 kg/ha respectively for grain, straw, biomass and equivalent grain yield.

Dynamics in the *Kharif* 2018

The age of trees was three year at the time of sowing of soybean crop in the *Kharif* 2018. The analysed data of grain yield, straw yield, biomass yield and equivalent grain yield are presented in [Table-2]. The yield attributes of soya bean crop in each treatment shown in [Fig-1].

Grain yield analysis in [Table-2] reveals that significant difference is recorded in treatments. Significantly highest yield is recorded in agroforestry (AF) with 100% Aonla (1109 kg/ha), however it is at par with 75% Aonla+25% *Sissoo* (1037 kg/ha). Significantly lowest yield is recorded in agroforestry (AF) with 100% Sissoo (752 kg/ha). Grain yields are moderate and at par in AF 25% Aonla + 75% Sissoo (954 kg/ha), 50% Aonla + 50% Sissoo (979 kg/ha) and 75% Aonla + 25% Sissoo (1037 kg/ha). Almost similar trend is also observed in the straw yield and biomass yield.

Equivalent grain yield is significantly highest in 100% Aonla (1238 kg/ha), however it is at par with 75% Aonla+25% Sissoo (1159 kg/ha). Significantly lowest yield is recorded in agroforestry (AF) with 100% Sissoo (853 kg/ha). Equivalent grain yields are moderate and at par in AF 25% Aonla + 75% Sissoo (1062 kg/ha), 50% Aonla + 50% Sissoo (1096 kg/ha) and 75% Aonla + 25% Sissoo (1159 kg/ha). The age of trees is 3-year in 2018 and it start to effect under storey crop. The overall mean yield in the year 2018 was 966 kg/ha, 1569 kg/ha, 2535 kg/ha and 1081 kg/ha respectively for grain, straw, biomass and equivalent grain yield.

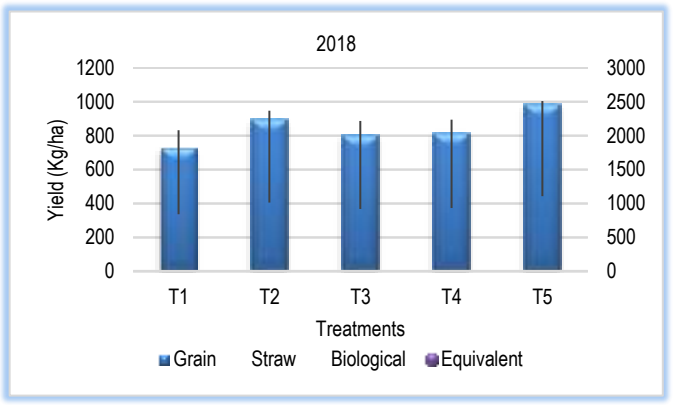

Fig-1 The yield attributes of Soya bean crop in 2018. The effect of treatments on crop attributes shown.

Dynamics in the *Kharif* 2019

The age of trees was four year at the time of sowing of soybean crop in the *Kharif* 2019. The analysed data of grain yield, straw yield, biomass yield and equivalent grain yield are presented in [Table-3]. As evident from [Table-3], significantly highest yield is recorded in agroforestry (AF) with 100% Aonla (982 kg/ha). It is followed by 75% Aonla+25% Sissoo (897 kg/ha). Grain yields are moderate and at par in AF 25% Aonla+ 75% Sissoo (804 kg/ha) and 50% Aonla + 50% Sissoo (817 kg/ha). Significantly lowest yield is recorded in agroforestry (AF) with 100% Sissoo (732 kg/ha). Almost similar trend is also observed in the straw yield and biomass yield. Equivalent grain yield is significantly highest in 100% Aonla (1106 kg/ha). It is followed by 75% Aonla+25% Sissoo (1015 kg/ha). Equivalent grain yield is moderate and at par in AF 25% Aonla + 75% Sissoo (918 kg/ha) and 50% Aonla + 50% Sissoo (932 kg/ha). Significantly lowest yield is recorded in agroforestry (AF) with 100% Sissoo (841 kg/ha). The age of trees is 4-year in 2019 and is affecting the under-storey crop significantly. The overall mean equivalent grain yield in the year 2019 was 846 kg/ha. The mean straw yield was 1437 kg/ha. The mean biomass yield was 2283 kg/ha. The mean equivalent grain yield was 963 kg/ha.

Mean grain yield of soybean was 1200 kg/ha in 2017, 966 kg/ha in 2018 and 846 kg/ha in2019.The grain yield of soybean is in declining trend as the age of system increased. The average reduction in grain yield is from 19.5 to 29.5% from 2017 to 2019. However, the reduction in straw yield for same duration is from13.1 to 20.4%. The reduction in biomass yield for same duration is from15.7 to 24.1%. Corresponding reduction in equivalent grain yield is from 18 to 27%. Trend of reduction in grain, straw and equivalent grain yield of under storey crop may be result of canopy development & expansion of rooting structure of trees. The trends of treatments effect on each yield attributes *viz*; grain, straw, biological & soya bean equivalent yield shown in [Fig-2].

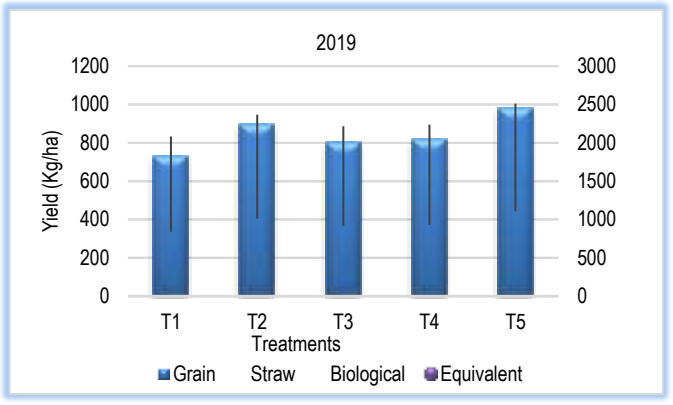

Fig-2 Treatment effect on trends of soya bean yield attributes in 2019

Discussion

The mean yield of grain, straw, biomass and equivalent grain of the experiment are in declined trend from 2017 to 2019. It may be due to development of tree canopy and tree root expansion with the age of trees.

Table-1 *Treatment wise grain, straw, biomass & equivalent grain yield of soybean in Kharif 2017*

SN	Treatments	Soybean Grain Yield	Soybean Straw Yield	Soybean Biomass Yield kg/ha	Soybean Equivalent grain yield
		kg/ha	kg/ha		kg/ha
1	100% *D. sissoo*	1232	1832	3063	1352
2	75% *E. officinalis* + 25% *D. sissoo*	1227	1827	3054	1347
3	25% *E. officinalis* + 75% *D. sissoo*	1165	1763	2929	1281
4	50% *E. officinalis* + 50% *D. sissoo*	1185	1784	2970	1302
5	100% *E. officinalis*	1192	1825	3017	1312
	CV %	7.86	4.79	5.94	7.56
	SEM±	66.74	61.17	126.36	70.50
	CD at 1%	203.9	186.87	386.04	215.36
	CD at 5%	145.44 (NS)	133.29 (NS)	275.35 (NS)	153.61 (NS)

Table-2 *Treatment wise grain, straw, biomass & equivalent grain yield of soybean in Kharif 2018*

SN	Treatments	Soybean Grain Yield	Soybean Straw Yield	Soybean Biomass Yield kg/ha	Soybean Equivalent grain yield
		kg/ha	kg/ha		kg/ha
1	100% *D. sissoo*	752	1373	2125	853
2	75% *E. officinalis* + 25% *D. sissoo*	1037	1661	2698	1159
3	25% *E. officinalis* + 75% *D. sissoo*	954	1459	2413	1062
4	50% *E. officinalis* + 50% *D. sissoo*	979	1594	2572	1096
5	100% *E. officinalis*	1109	1758	2867	1238
	CV %	8.61	8.03	7.60	8.30
	SEM±	58.80	89.06	136.27	63.49
	CD at 1%	179.62	272.09	416.37	193.96
	CD at 5%	128.12	194.07	296.37	138.35

Table-3 *Treatment wise grain, straw, biomass & equivalent grain yield of soybean in Kharif 2019*

SN	Treatments	Soybean Grain Yield	Soybean Straw Yield	Soybean Biomass Yield kg/ha	Soybean Equivalent grain yield
		kg/ha	kg/ha		kg/ha
1	100% *D. sissoo*	732	1351	2083	841
2	75% *E. officinalis* + 25% *D. sissoo*	897	1471	2368	1015
3	25% *E. officinalis* + 75% *D. sissoo*	804	1414	2218	918
4	50% *E. officinalis* + 50% *D. sissoo*	817	1419	2236	932
5	100% *E. officinalis*	982	1530	2512	1106
	CV %	5.24	3.27	3.24	4.75
	SEM±	31.37	33.19	52.35	32.31
	CD at 1%	95.84	101.39	159.92	98.69
	CD at 5%	68.36	72.31	114.06	70.39

As the age of tree increases, the competition with under storey crop gradually increased for light, space, moisture, and nutrient. The same trend was observed by many researchers in their findings across the globe, [10-14].

In the year 2017 the age of tree was only two years. In this year there was no significant variation in the yields of different treatments. The mean grain, straw, biomass and equivalent grain yield of different treatments was at par. It may be due to less expansion of canopy and lateral roots of trees. The same findings were observed by research workers. Mutanal *et al*. (2009) [15] reported that there was no variation of yield in Soybean under different tree species for first two years. The age of tree become 3-year in *Kharif* 2018. Tree increases its biomass which affect the yield of soybean in few treatments however this effect is partial.

In the *Kharif* 2019 the age of tree become 4-year. Its height, canopy and lateral roots expanded. In this year the impact of tree growth was more pronounced on under storey crop.

There was significant variation in grain, straw, biomass and equivalent grain yields among the selected five treatments. The strong competition in agroforestry system for resources like light, space, moisture and nutrient affect the yield of crops in various manners [16-20]. The yield below sissoo was significantly lower and below Aonla significantly higher among the treatments.

Dalbergia sissoo, have strong habit to produce more side roots (sucker) and closed crown canopy. The *Emblica officinalis* have phyllode type of leaf morphology; make easy availability of light & moisture to under storey crop. The leaves of *Emblica officinalis* decomposed easily compare to sissoo leaves. Higher rate of litter decomposition makes easy availability of nutrient to under storey crop. Morphological characters of tree contribute a reasonable impact to reduce tree-crop competition in agroforestry system. The micro climate created by tree species play significant role to yield attributes of under storey crop. The significant impact of micro climate on crop yield was also observed by several workers in their findings [21-26].

Conclusion

Emblica officinalis is a horticulture crop whereas *Dalbergia sissoo* is a silvicultural crop. The following conclusions are emerged from the study:

At the early age of tree in this Agri-horti-silviculture system soybean production is at par in all selected five treatments hence any treatment may be preferred by farmers.

In later year if farmers do not desire timber then 100% Aonla+ soybean may be grown.

If farmers desire timber, Aonla fruits and soybean then soybean may produce as under storey crop with 75% Aonla +25% Sissoo combinations.

Though yield is reduced with the age of trees but this may be compensated by timber and fruit productions however it needs further study.

Application of research: The Agri-horti-silviculture system is more profitable and preferred by farmers. Biologically this system is more productive for a unit of land as compare to mono crop. On the other hand, these systems are less risky for farmers compare to annual crops where climate change mark great concerned.

Research Category: Agri-horti-silviculture

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Research project name or number: Research station study

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: ICAR-Krishi Vigyan Kendra (KVK), IGNTU, Amarkantak

Cultivar / Variety / Breed name: *D. sissoo, E. officinalis*

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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