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Effect of soybean [*Glycine max* (L.) Merrill] based cropping systems on biomass production in *Vertisols* of Madhya Pradesh

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Abstract
The present investigation was conducted to study "Effect of soybean [*Glycine max* (L.) Merrill] based cropping systems on biomass production in *Vertisols* of Madhya Pradesh" during *kharif, rabi* and *zaid* seasons of 2015-16 and 2016-17. The soil of the experimental field was clay loam in texture, neutral in reaction (pH 7.60) with normal EC (0.58 dS/m) and medium organic carbon contents (0.59%) and analysing low in available N (218 kg/ha), medium in available P (11.60 kg/ha) and high in available K (350 kg/ha) contents. In present study, Soybean was sequenced with feasible *rabi* viz. Wheat (*Triticum aestivum* & *Triticum durum* L.), Chick pea (*Cicer arietinum* L.), Garlic (*Allium sativum* L.), Onion (*Allium cepa* L.), Potato (*Solanum tuberosum* L.) and garden pea (*Pisum sativum* L.) with inclusion of Garlic (*Allium sativum* L.*),* Onion (*Allium cepa* L.) in *zaid* consisted 16 cropping sequences and tested in randomized block design with four replications. Inclusion of Garlic (*Allium sativum* L.*)* and Onion (*Allium cepa* L.) during *zaid* significantly increased the soybean-equivalent yield. Soybean (JS 93-05) - wheat (HI-8663) durum cropping sequence recorded the highest total biomass production (48.87 q/ha) followed by soybean (JS 93-05)-garden pea (Arkel)-garlic (G-282) during *kharif* season and treatment soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) recorded highest biomass production (298.50 q/ha) whereas biomass production was found maximum (209.42 q/ha) under treatment soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) during *zaid.* The maximum seed soybean equivalent yield (177.31 q/ha) was significantly recorded under soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) as compared to existing cropping system (soybean-chickpea and soybean-wheat).

Keywords: Cropping sequences, soybean equivalent yield, biomass production

Introduction
Soybean [*Glycine max* (L.) Merrill] is a major legume crop recognized as the efficient producer of the two scarce quality characters *i.e.* the protein and oil, which are not only the major components in the diet of vegetarians mass but a boon to the developing countries as well. Due to short growing season, soybean fits well in a number of cropping systems and is well suited for intercropping with a number of crops resulting in better land equivalent ratio and helps in the risk aversion due to climatic uncertainties in rainfed conditions.

Generally, soybean is grown as a monsoon season crop under rainfed situation mainly under *Vertisols* and associated soils. It has resulted increased cropping intensity and profitability. In Malwa and Nimar valley region, its cultivation is largely practiced in rainy season followed by Gram/wheat on conserved soil moisture. Under irrigated conditions, soybean is largely grown in soybean-wheat cropping system, while soybean-chickpea cropping system is prevalent under rainfed conditions. The major cropping system in the *Vertisols* and associated soils of Central India under regime is soybean-wheat in which soybean is a rainfed crop. Both soybean and wheat are most productive crops and predominantly grown in a sequential cropping, particularly under irrigated production system in *Vertisols* of Madhya Pradesh. Soybean-chickpea system is also prevalent as a next important cropping sequence mainly in those areas, where rainfall is not adequate or irrigation water is scarce. Generally, cultivation of both Soybean and wheat in a sequence are nutrients exhaustive and these crops require heavy investment in desirable agricultural operations during their cultivation. Long term regular practice of Soybean-Chickpea and Soybean-Wheat system in the growing region is posing severe problems before the growers such as complexity in weed management, deterioration of soil-properties, delayed sowing of wheat and low market value of produce owing low productivity as well as poor economic viability of this cropping system.

Soybean contributes considerable biomass of N to the soil through left over biomass. The left over biomass of soybean comprised of shatter leaves (after senescence) and nodulated roots, in addition to organic biomass contributed through fine root decay and exude during the growing

period. Leaf fall during crop legume development and the nodulated roots can each contain up to 40 kg N/ha and yield benefit of the succeeding non legume crops are very often attributed to the residue fixed N locked in the left over crop biomass.

All domestic demands of the farmers pertaining to agricultural produce could not be possible to fulfill by growing crops in existing Soybean-wheat/gram cropping systems. The market values of soybean and wheat are comparatively low than pulses, oilseeds and vegetable crops. Therefore, the purchasing capacity of the farmers to meet out their demands of vegetables, fruits, edible oil and pulses declines from the value realized by the produce of soybean and wheat crops. Under such circumstances, the diversification of existing soybean -wheat/chickpea system needs to be evaluated to meet the domestic need of farmers. Simultaneously, the economic status of the farmers of Soybean-wheat growing areas will also be raised by replacing any of the two crop components with the introduction of high value crop without degrading the land-resources. Consequent upon above facts, evaluation of suitable diversified cropping system under existing agro-ecological and farming situation needs to be identified through proper investigation.

Therefore socio-economic status of the farmers associated with prevailing soybean based cropping systems in the region is quite low. Since the number of crops being grown during rabi season in district Dhar of Malwa region is relatively more than other districts, though in relatively smaller area e.g. chickpea, garlic, onion, potato, garden pea etc. Under such circumstances, the diversification of crops under soybean based cropping system appears to be a possible way for improving the productivity and profitability per unit area per year without jeopardizing the soil health. The resource use efficiency viz., land use efficiency and water productivity and employment opportunities can be increased with diversification of soybean based cropping system with minimization of agricultural risks. Hence, diversification of cropping system is necessary to get higher yield, net returns, maintain soil health, preserve environment and meet daily food and fodder requirement of human and animals.

Materials and Methods

The present investigation was conducted for two years *i.e.* 2015-16 and 2016-17 at Research Farm of Krishi Vigyan Kendra, Dhar (M.P.) Temperature extremes vary between a minimum temperature of 12 ^{0}C in December and January months to maximum temperature of 45 ^{0}C in May and June. The soil of the field was a typical medium black soil. Due to dominance of Montmorillonite clay content it has high capacity to swell and shrink and high CEC. The experiment comprised 16 cropping sequences, soybean was sequenced with feasible *rabi* viz. Wheat (*Triticum aestivum* & *Triticum durum* L.), Chick pea (*Cicer arietinum* L.), Garlic (*Allium sativum* L.), Onion (*Allium cepa* L.), Potato (*Solanum tuberosum* L.) and garden pea (*Pisum sativum* L.) with inclusion of Garlic (*Allium sativum* L.), Onion (*Allium cepa* L.) in *zaid* and tested in randomized block design with four replications.

Only soybean crop was grown during *kharif* season with two varieties i.e. JS 95-60 early duration (82-87 days) and JS 93-05 medium duration (90-95 days) under all crop- sequences, Different varieties were grown under various need based diversified intensive crop sequences as per their feasibility to accommodate the succeeding crop under present investigation, The soybean varieties tested under study were JS 95-60 (a high yielder widely accepted by the farmers in the locality), JS 93-05 (a medium duration high yielding). The variety used for *rabi* crops was like wheat (HI-1544) aestivum, wheat (HI-8663) durum, chickpea (JG-130) desi, chickpea (RVKG-101) kabuli, Potato (Kufri jyoti), garden pea (Arkel) and garlic (G-282) and onion (AFLR) during zaid, respectively. Sowing of different crops under different crop sequences was done as per recommended package of practices for crops under irrigated condition. The recommended dose of N:P:K (kg/ha) for soybean 20:80:20, wheat 120:60:40, chick pea 20:60:20, garlic 100:50:50, onion 100:75:50, potato 120:50:100 and garden pea 20:60:20 was applied. The nitrogen, phosphorus and potash were applied through urea, single super phosphate and muriate of potash, respectively.

The cropping sequences were evaluated in terms of seed and straw soybean-equivalent yield.

$$\text{Seed soybean equivalent yield (q/ha)} = \frac{\text{Grain/tuber/bulb yield of a crop (q/ha) x Price of yield (₹/q)}}{\text{Price of soybean yield (₹/q)}}$$

$$\text{Straw Soybean equivalent yield (q/ha)} = \frac{\text{Straw/haulm yield of a crop (q/ha) x Price of straw (₹/q)}}{\text{Price of soybean straw (₹/q)}}$$

Results and Discussion

Crop productivity

Seed and straw yield of soybean crop during *kharif* season and during *rabi* season, grain and straw in wheat, seed and straw in chick pea and garden pea, tuber and haulm in potato, bulb and haulm in onion and garlic were recorded and then converted in total biomass (seed/tuber/bulb and straw/haulm) production. During *kharif* season, the maximum seed yield of soybean (21.58 q/ha) was recorded in treatment T_{14}- soybean (JS 93-05)-onion (AFLR) and lowest (19.04 q/ha) was recorded in T_4- soybean (JS 95-60)-chick pea (RVKG-101) Kabuli. During *rabi* season onion crop recorded maximum bulb yield (220.79 q/ha) in T_{14}- soybean (JS 93-05)-onion (AFLR). The highest bulb yield (195.67) was recorded in *zaid* onion.

The maximum straw yield of soybean (29.13 q/ha) was recorded in T_8- Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282) and minimum (24.89 was in T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282).

Total biological yield of soybean was registered in T_{10}- soybean (JS 93-05)-wheat (HI-86.63) durum and lowest (43.94 q/ha) was recorded in T_{14}- soybean (JS 93-05)-onion (AFLR) during *kharif* season whereas the maximum biological yield (298.50 q/ha) was recorded in T_{15}-Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR) and lowest (39.0 q/ha) was recorded in Soybean (JS 95-60) - Chickpea (JG-130) desi system. During *zaid* season, the maximum (209.42 q/ha) was found in T_{15}-Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR).

Table 1: Total biomass production of different crops during *Kharif, Rabi* and *Zaid* season

Crop sequences		Seed/grain/tuber/bulb yield (q/ha) #			Straw/haulm yield (q/ha) ##			Biological yield (q/ha)		
		Kharif	*Rabi*	*Zaid*	*Kharif*	*Rabi*	*Zaid*	*Kharif*	*Rabi*	*Zaid*
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	18.83	47.57	-	25.85	65.86	-	44.67	113.40	-
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	18.48	51.23	-	26.43	63.73	-	44.91	115.00	-
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	18.94	16.38	-	28.39	22.67	-	47.33	39.00	-
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	19.73	17.96	-	26.89	23.73	-	46.62	41.70	-
T_5	Soybean (JS 95-60) - Garlic (G-282)	20.28	84.09	-	27.43	13.62	-	47.71	97.70	-
T_6	Soybean (JS 95-60) - Onion (AFLR)	19.22	220.09	-	27.16	12.80	-	46.38	232.90	-
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	19.08	186.92	189.08	27.16	109.94	12.47	46.24	296.90	201.55
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	19.35	12.09	70.08	29.13	15.12	13.00	48.48	27.20	83.08
T_9	Soybean (JS 93-05) - Wheat (HI-1544) aestivum	20.41	47.81	-	27.51	67.02	-	47.92	114.80	-
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	21.49	51.48	-	27.39	66.10	-	48.87	117.60	-
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	20.53	16.38	-	28.22	22.65	-	48.74	39.00	-
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	19.53	17.96	-	25.77	24.35	-	45.30	42.30	-
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	20.03	85.04	-	25.20	14.35	-	45.23	99.40	-
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	19.03	220.79	-	24.91	13.34	-	43.94	234.10	-
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	19.15	187.28	195.67	24.89	111.25	13.75	44.04	298.50	209.42
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	19.75	12.44	72.13	25.49	15.85	13.90	45.24	28.30	86.03

Grain yields (q/ha)# = Grain yield in wheat, seed yield in chick pea, tuber in potato, bulb yield in onion and garlic
Straw yield (q/ha)##= Straw yield in wheat, chick pea and garden pea, haulm yield in onion, garlic and potato.

System Productivity

Soybean Yield Equivalent (SEY) of cropping-system as a whole, T_{15}-Soybean (JS 93-05)-Potato (Kufri jyoti)-Onion (AFLR) system was recorded significantly maximum SEYs (177.31 q/ha) among all crop-sequences mainly due to greater SEY of potato during *Rabi* along with considering good SEYs of onion in *zaid* season. The next best crop- sequence was T_7 - Soybean (JS 95-60)-Potato (Kufri jyoti)-Onion (AFLR) with regard to SEYs (173.18 q/ha) mainly owingto the higher SEYs in k*harif* soybean and r*abi* potato and onion in *zaid* followed by SEY 104.43 q/ha in T_{14}- Soybean (JS 93-05) - Onion (AFLR), SEY 101.24 q/ha in T_6- Soybean (JS 95-60) - Onion (AFLR), SEY 93.44 q/ha in T_{16}- Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282) and SEY 90.06 q/ha in T_8- Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282). The higher SEYs in Soybean (JS 93-05) - Onion (AFLR) and Soybean (JS 95-60) - Onion (AFLR) cropping sequences was become of higher yield of onion in the sequence. Further, the results revealed that there is sufficient scope to intensify the existing cropping sequence with inclusion of onion and garlic during *zaid*. Inclusion of onion and garlic during *zaid* increased cropping sequence productivity. The minimum productivity of the cropping sequence based on SEYs was registered in Soybean (JS 95-60) - Chickpea (JG-130) desi i.e. 42.79 q/ha. This could be ascribed due to low yield realized from desi chick pea in the sequence. Several researchers have also reported heterogeneity in production of potential varying crop-sequences from different agro- production systems (Tyagi *et al.*, 2011; Chitale *et al.*, 2011; Narkhede, *et al.*, 2011; Kumar, *et al.*, 2012; Billore 2013, Gallani *et al.*, 2013, Shrikant *et al.*, 2013; Singh *et al.*, 2013; Meena *et al.*, 2013, Prajapat *et al.*, 2014; Singh and Kumar, 2014; Shridhara *et. al.*, 2017; Singh *et al.*, 2017; Turkhede *et al.*, 2017; Chavan *et al.*, 2018; Jugnahake *et al.*, 2018; Sammauria, *et al.*, 2018; Bhargavi and Behera, 2019) [18, 10, 8, 2, 9, 3, 15, 9, 12, 5].

Conclusion

Among all crop-sequences tested, the maximum seed soybean equivalent yield (SEY) (177.31 q/ha) was significantly recorded in T_{15}- Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR) cropping sequence. The next best cropping system in this regard was T_7 - Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR) (173.18 q/ha), T_{14}- Soybean (JS 93-05) - Onion (AFLR) system (104.43 q/ha), T_6- Soybean (JS 95-60) - Onion (AFLR) (101.24 q/ha) while maximum straw soybean equivalent yield (87.64 q/ha) was significantly recorded in T_8- Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282) as compared to existing cropping sequences (soybean-wheat and soybean-chick pea).

Table 2: Mean seed and straw Soybean Equivalent Yield (q/ha) in different seasons under various crop sequences

Crop sequences		Grain/seed/tuber SEY (q/ha)				Straw/haulm SEY (q/ha)			
		Kharif Season	*Rabi* Season	*Zaid* Season	Total	*Kharif* Season	*Rabi* Season	*Zaid* Season	Total
T_1	Soybean (JS 95-60) - Wheat (HI-1544) aestivum	18.78	30.08	-	49.09	25.85	21.54	-	47.39
T_2	Soybean (JS 95-60) - Wheat (HI-8663) durum	19.09	31.99	-	51.17	26.43	22.03	-	48.46
T_3	Soybean (JS 95-60) - Chickpea (JG-130) desi	19.46	23.33	-	42.79	28.39	39.43	-	67.82
T_4	Soybean (JS 95-60) - Chickpea (RVKG-101) Kabuli	19.04	28.77	-	47.83	26.89	37.35	-	64.24
T_5	Soybean (JS 95-60) - Garlic (G-282)	19.75	62.28	-	82.03	27.43	38.10	-	65.53
T_6	Soybean (JS 95-60) - Onion (AFLR)	19.76	82.01	-	101.24	27.16	37.72	-	64.88
T_7	Soybean (JS 95-60) - Potato (Kufri jyoti) - Onion (AFLR)	20.18	83.08	70.03	173.18	27.16	37.72	17.32	82.20
T_8	Soybean (JS 95-60) - Garden pea (Arkel) - Garlic (G-282)	20.24	17.91	52.41	90.06	29.13	40.46	18.06	87.64
T_9	Soybean (JS 93-05) - Wheat (HI-1544)	20.84	31.99	-	52.83	27.51	22.93	-	50.44

	aestivum								
T_{10}	Soybean (JS 93-05) - Wheat (HI-8663) durum	20.62	33.20	-	54.33	27.39	22.83	-	50.22
T_{11}	Soybean (JS 93-05) - Chickpea (JG-130) desi	20.56	24.13	-	44.81	28.22	39.19	-	67.41
T_{12}	Soybean (JS 93-05) - Chickpea (RVKG-101) Kabuli	20.38	29.50	-	49.88	25.77	35.79	-	61.56
T_{13}	Soybean (JS 93-05) - Garlic (G-282)	21.18	47.03	-	84.19	25.20	35.00	-	60.20
T_{14}	Soybean (JS 93-05) - Onion (AFLR)	21.58	83.48	-	104.43	24.91	34.60	-	59.51
T_{15}	Soybean (JS 93-05) - Potato (Kufri jyoti) - Onion (AFLR)	21.29	83.55	72.47	177.31	24.89	34.57	19.10	78.56
T_{16}	Soybean (JS 93-05) - Garden pea (Arkel) - Garlic (G-282)	21.56	18.58	53.42	93.44	25.49	35.40	19.31	80.20
	SEm±	0.39	1.60	0.48	1.12	0.88	0.91	0.38	1.82
	CD (P=0.05)	1.09	4.48	1.33	3.15	2.50	2.60	1.08	5.19

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