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Comparative Studies of Soybean (*Glycine max* L.) based Cropping Systems for Sustainable Production in Malwa Plateau of Central India

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ABSTRACT

Background: Large area under soybean is spread over Central India. 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. It has increased more cropping intensity and B;C ratio (profitability). 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.

Methods: A field trial was conducted during rainy, winter and *late* winter seasons of the year 2015-16 and 2016-17 at the research farm of Krishi Vigyan Kendra, Dhar, M.P. to assess comparative studies of soybean (*Glycine max* L.) based cropping systems for sustainable production in Malwa Plateau of Central India. There were altogether16 treatments comprising of soybean sequenced with wheat, chick pea, garlic, onion, potato and garden pea with inclusion of garlic, onion in *late* winter and assessed in randomized block design with four replications.

Result: Soybean (JS 93-05) - potato (Kufri jyoti) - onion (AFLR) cropping sequence recorded the highest system productivity 177.31 q/ha) in terms of soybean equivalent yield with greater production efficiency (56.55 kg/ha/day), land use efficiency (85.89%) and sustainable yield index (0.91) while existing crop sequence *viz.* T_3- soybean (JS 95-60) - chickpea (JG-130) recorded minimum soybean equivalent yield (42.79 q/ha) with production efficiency (22.93 kg/ha/day), use efficiency of land (56.30%) and sustainable yield index (0.50).

Key words: Land use efficiency, Production efficiency, Soybean based cropping systems, Soybean equivalent yield, Sustainable yield index.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is a high valued and profitable crop. It is capable to supply the edible oil (20%) and protein (40%) among people and fulfill the gap between the demand and supply of both. Soybean and wheat are most productive crops and predominantly grown in a sequential cropping, particularly under irrigated cropping production system in almost periphery of Malwa and Nimar Valley zone of India. 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. In Malwa plateau of Central region especially in Dhar district, many growers are growing soybean crop due to better suitability to biotic and abiotic climatic factors. Soybean is not only an important pulse crop but also known as oilseed crop in the Malwa plateau. In India, it is grown on an area of about 11.33 million hectares, which is likely to produce more than 13.79 million tonnes with productivity 1217 kg/ha during the year 2019-20 (Anonymous, 2020).

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. Hence, the diversification and intensification of existing soybean - wheat/chickpea cropping sequence needs to be evaluated to meet the domestic need of farmers under such circumstances. 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.

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Therefore, the farmers' status (socially and economically both) associated with prevailing soybean based cropping systems in the region are quite low. Since the number of crops being grown during winter season in Malwa region is relatively more than other districts, though in relatively smaller area *e.g.* chickpea, garlic, onion, potato, garden pea *etc.* Thus, the diversification and intensification of various crops under soybean based cropping sequences is a possible way for increasing the productivity and profitability per unit area per year without deteriorating the soil fertility. The land and water use efficiency and employment opportunities can be enhanced with diversification and intensification of soybean based cropping systems with minimization of cultivation risks.

MATERIALS AND METHODS

A field experiment was conducted during rainy, winter and *late* winter seasons of the year 2015-16 and 2016-17 at experimental field of Krishi Vigyan Kendra, Dhar (M.P.). It belongs to "Malwa region" under 10th agroclimatic zone of Central India. The experiment comprised of 16 cropping sequences, soybean was sequenced with feasible *rabi viz.* wheat (*Triticum aestivum* and *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 *late rabi* and tested in randomized block design with 4 replications.

Only soybean was grown during rainy 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 cropping sequences. Different varieties as per their feasibility to accommodate the succeeding crop under present investigation were cultivated under different need based diversified cropping sequences. 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 late *rabi*, respectively. Sowing of rainy, winter and late winter season crops were done on 21.06.15 and 26.06.16; 17.10.15 and 21.10.16 and 02.01.16 and 03.01.17 during two consecutive years, respectively. 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 observations of experiment were recorded as per standard procedure. The experimental data was statistically analysed given by Gomez and Gomez (1984). The differences among treatments were calculated by using 'F' test and critically differences at 5% probability.

The methods of calculation of various cropping system indices with their references are as follows:

Soybean equivalent yield (SEY)

The cropping sequences were evaluated in terms of soybean-equivalent yield as suggested by Yadav and Newaj (1990).

$$\text{Soybean equivalent yield (q/ha)} = \frac{\text{Yield of a crop (q/ha)} \times \text{Price of yield (`/q)}}{\text{Price of soybean yield (`/q)}}$$

The production efficiency (system productivity) of each crop sequence was worked out treatment wise with the help of following formula as suggested by Tomar and Tiwari (1990):

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Soybean equivalent yield (kg/ha) of a particular crop sequences}}{\text{Total duration of all crop components of the same crop sequence (days)}}$$

Land use efficiency has been defined as the number of days during which the crop occupy the land during a year divided by days in a year (365) and can be expressed as a percentage. It was calculated as-

$$\text{Land use efficiency (\%)} = \frac{\text{Duration of a crop sequence}}{\text{Days in a year (365)}} \times 100$$

Crop duration refers to be total number of days in crop cycle when land was kept under crops during different seasons of a under a particular crop-sequence sustainable yield index was worked out using the formula given by Singh *et al*. (1990):

$$\text{Sustainable yield index} = \frac{Y_a - \sigma}{Y_{max}}$$

Where,

Y_a is the estimated mean yield, 'σ' the estimated standard deviation and Y_{max} is the observed maximum yield obtained under cropping sequences.

RESULTS AND DISCUSSION

Production efficiency

Among different crop-sequences tested, the production efficiency (56.56 kg/ha/day) was observed highest in (T_{15}) soybean - potato - onion followed by (T_7) soybean (JS 95-60) - potato - onion 56.42 kg/ha/day than existing cropping sequences of the Malwa plateau and Nimar valley *viz.* soybean - chick pea 20.47 kg/ha/day, soybean - chick pea 21.29 kg/ha/day (Table 2). The superiority of the production efficiency was due to relatively higher SEY from potato and onion crops during winter season and inclusion of onion during *late* winter under these two cropping systems. Similar results were reported by Billore *et al.* (2013), Gallani *et al.* (2013), Kumar and Kushwaha (2020).

System productivity

Results revealed that among all cropping sequences, Soybean - potato - onion system (T_{15}) recorded maximum SEY mainly due to higher SEY of potato during winter along

with higher SEYs of onion in late winter season whereas the minimum SEY was noted in soybean - chickpea (T_3) and soybean - chickpea *desi* (T_{11}) (42.79 and 44.81 q/ha) during the consecutive years and pooled data basis. The higher SEYs in soybean - onion and soybean - onion cropping sequences might be due to higher yield of onion in the sequence. Further, the results revealed that there is enough scope to intensify the existing cropping sequence with inclusion of onion and garlic during late winter. Inclusion of onion and garlic during late winter increased cropping sequence productivity. Similar finding was reported Prajapat *et al.* (2014) and Narolia *et al.* (2018) (Table 1).

Crop duration

Crop duration refers to be total number of days in crop cycle when land was kept under crops during different seasons of a particular crop-sequence. The land were engaged under crops for more than 300 days within a year under all four Intensive diversified crop-sequences *viz.* soybean - potato - onion (314 days T_{15}) followed by soybean - potato - onion (306 days T_7), soybean (JS 93-05) - garden pea (Arkel) - garlic (G-282) (289 days T_{16}), soybean - garden pea -garlic (283.5 days T_8) while, existing crop-sequences *viz.* soybean-chickpea (T_3, T_{11}) and soybean-wheat (T_1, T_9) engaged only 205.5 and 210.5 days, respectively (Table 3).

Land or resource use efficiency

Land use efficiency increased significantly with inclusion of onion and garlic during late winter in four treatments *viz.* - soybean - potato - onion (T_7), soybean - garden pea - garlic (T_8), soybean - potato - onion (T_{15}) and soybean - garden pea - garlic (T_{16}). However, on pooled data basis, the highest land use efficiency (85.89%) was observed in soybean - potato - onion (T_{15}) which was appreciably higher during both the years than all other treatments, closely followed by soybean - potato - onion T_7 (83.84%) as compared to existing cropping sequences *viz.* soybean - chickpea *kabuli* T_4 and soybean-chick pea T_{11} (56.30% and 57.67%) respectively. Land use efficiency was recorded in soybean - potato - onion T_{15} occupied the field for a maximum period of 313.5 days and hence, the LUE of the systems having potato-onion was found maximum. Intensification of soybean based cropping sequence by growing *late* winter onion and garlic recorded markedly higher land use efficiency than crop sequences without late winter crops *viz.* soybean-chickpea *desi* (56.30%) and soybean-wheat sequence (58.63%). Similar results were found Tyagi *et al.* (2011) and Prajapat *et al.* (2014).

Sustainable yield index (SYI)

The soybean crop recorded highest sustainable yield index (0.54) during *kharif* season, when it sequenced with treatment soybean - potato - onion T_{15} followed by soybean - potato - onion T_7 (0.51) and lowest sustainable yield index (0.42) was observed in soybean - chickpea desi. In winter season among the various crops raised in soybean based sequences, potato registered the highest sustainable yield index (0.95) in soybean - potato - onion T_{15}, while chickpea (desi) recorded the lowest sustainable yield index (0.37) in soybean - chickpea *desi* T_3. In late winter, maximum sustainable yield index (0.91) was recorded in onion (T_{15}) and lowest (0.82) was recorded in soybean - garden pea - garlic T_3. Similar results were reported by Srikant *et al.* (2013), Jugnahake *et al.* (2018), Singh and Kushwaha (2018).

Maximum cropping sequence sustainable yield index (0.91) was noted in soybean - potato - onion T_{15} sequence

Table 1: Mean soybean equivalent yield (q/ha) in different seasons under various crop sequences.

Crop sequences		2015-16			2016-17		
		Rainy season	Winter season	Late winter season	Rainy season	Winter season	Late winter season
T_1	Soybean - Wheat *aestivum*	18.41	29.14	-	19.60	31.03	-
T_2	Soybean - Wheat *durum*	18.48	30.91	-	19.87	33.08	-
T_3	Soybean - Chickpea *desi*	18.81	22.65	-	20.11	24.00	-
T_4	Soybean - Chickpea *Kabuli*	19.05	27.68	-	19.03	29.90	-
T_5	Soybean - Garlic	19.37	61.80	-	20.13	62.77	-
T_6	Soybean - Onion	19.30	79.26	-	20.22	83.77	-
T_7	Soybean - Potato - Onion	19.58	79.86	68.73	20.78	86.29	71.33
T_8	Soybean - Garden pea - Garlic	20.02	17.19	50.67	20.46	18.63	53.15
T_9	Soybean - Wheat *aestivum*	20.43	30.91	-	21.25	33.08	-
T_{10}	Soybean - Wheat *durum*	20.17	32.60	-	21.08	34.80	-
T_{11}	Soybean - Chickpea *desi*	19.69	23.50	-	21.44	25.00	-
T_{12}	Soybean - Chickpea *Kabuli*	19.41	28.50	-	21.35	30.50	-
T_{13}	Soybean - Garlic	20.04	62.50	-	22.33	63.50	-
T_{14}	Soybean - Onion	20.31	81.50	-	22.85	85.20	-
T_{15}	Soybean - Potato - Onion	19.67	80.82	71.66	22.90	86.29	73.28
T_{16}	Soybean - Garden pea - Garlic	20.65	17.20	52.33	22.48	19.70	54.52
	SEm±	0.52	2.82	0.66	0.58	1.50	0.68
	CD (P=0.05)	1.47	8.07	1.90	1.66	4.29	1.95

followed by soybean - potato - onion (0.88 T_7) whereas minimum (0.50) was found under soybean - chickpea *desi* (T_3). The maximum sustainable yield index was registered due to inclusion of potato in winter and onion in late winter and also higher benefit cost ratio. Further, the results revealed that there is enough scope to intensify the existing cropping sequence with inclusion of onion and garlic during *late* winter. Inclusion of onion and garlic during l*ate* winter increased sustainable yield index (Table 4).

CONCLUSION

Among different diversified intensive crop sequences tested, soybean - potato - onion T_{15} system significantly proved to be the best with respect to total system productivity in terms of SEYs (177.31 q/ha) as well as production efficiency (56.55 kg/ha/day), land use efficiency (85.89%) and sustainable yield index (0.91) for assured irrigated production system under Malwa Plateau and Nimar valley of Madhya Pradesh. The next best crop sequence was found soybean - potato -

Table 2: Production efficiency and soybean equivalent yield in different seasons under various crop sequences.

Crop sequences		Production efficiency (kg/ha/day)			SEY (q/ha)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	Soybean - Wheat *aestivum*	22.64	23.22	22.93	47.55	50.63	49.09
T_2	Soybean - Wheat *durum*	23.19	23.99	23.59	49.39	52.95	51.17
T_3	Soybean - Chickpea *desi*	20.56	20.33	20.44	41.46	44.11	42.79
T_4	Soybean - Chickpea *Kabuli*	23.37	23.20	23.28	46.73	48.93	47.83
T_5	Soybean - Garlic	34.69	33.98	34.33	81.17	82.90	82.03
T_6	Soybean - Onion	43.23	43.52	43.37	98.55	103.92	101.24
T_7	Soybean - Potato - Onion	56.24	56.56	56.40	168.17	178.20	173.18
T_8	Soybean - Garden pea - Garlic	31.50	32.03	31.77	87.88	92.24	90.06
T_9	Soybean - Wheat *aestivum*	23.77	24.47	24.12	51.34	54.33	52.83
T_{10}	Soybean - Wheat *durum*	24.32	24.95	24.63	52.77	55.88	54.33
T_{11}	Soybean - Chickpea *desi*	21.07	21.49	21.28	43.19	46.44	44.81
T_{12}	Soybean - Chickpea *Kabuli*	22.26	24.12	23.19	47.91	51.85	49.88
T_{13}	Soybean - Garlic	34.83	34.75	34.79	82.54	85.83	84.19
T_{14}	Soybean - Onion	44.07	44.65	44.36	100.81	108.05	104.43
T_{15}	Soybean - Potato - Onion	56.08	57.02	56.55	172.15	182.47	177.31
T_{16}	Soybean - Garden pea - Garlic	31.64	33.01	32.33	90.18	96.70	93.44
	SEm±	0.84	0.68	0.54	1.41	1.75	1.12
	CD (P=0.05)	2.40	1.94	1.51	4.04	5.00	3.15

Table 3: Crop duration and land use efficiency (%) in different seasons under various crop sequences.

Crop sequences		Crop duration days			Land use efficiency (%)		
		2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1	Soybean - Wheat *aestivum*	210	218	214	57.53	59.73	58.63
T_2	Soybean - Wheat *durum*	213	221	217	58.36	60.55	59.46
T_3	Soybean - Chickpea *desi*	212	217	214	58.08	59.45	58.77
T_4	Soybean - Chickpea *Kabuli*	200	211	206	54.79	57.81	56.30
T_5	Soybean - Garlic	234	244	239	64.11	66.85	65.48
T_6	Soybean - Onion	228	239	234	62.47	65.48	63.98
T_7	Soybean - Potato - Onion	299	313	306	81.92	85.75	83.84
T_8	Soybean - Garden pea - Garlic	279	288	284	76.44	78.90	77.67
T_9	Soybean - Wheat *aestivum*	216	222	219	59.18	60.82	60.00
T_{10}	Soybean - Wheat *durum*	217	224	221	59.45	61.37	60.41
T_{11}	Soybean - Chickpea *desi*	205	216	211	56.16	59.18	57.67
T_{12}	Soybean - Chickpea *Kabuli*	206	215	211	56.44	58.90	57.67
T_{13}	Soybean - Garlic	237	247	242	64.93	67.67	66.30
T_{14}	Soybean - Onion	231	242	237	63.29	64.66	63.98
T_{15}	Soybean - Potato - Onion	307	320	314	84.11	87.67	85.89
T_{16}	Soybean - Garden pea - Garlic	285	293	289	78.08	80.27	79.18
	SEm±	-	-	-	1.94	2.14	1.45
	CD (P=0.05)	-	-	-	5.55	6.12	4.05

Table 4: Sustainable yield index in different seasons under various crop sequences.

Crop sequences		Sustainable yield index			
		Rainy season	Winter season	Late winter season	Cropping sequence
T_1	Soybean - Wheat *aestivum*	0.44	0.68	-	0.61
T_2	Soybean - Wheat *durum*	0.45	0.71	-	0.63
T_3	Soybean - Chickpea *desi*	0.42	0.37	-	0.50
T_4	Soybean - Chickpea *Kabuli*	0.43	0.41	-	0.51
T_5	Soybean - Garlic	0.44	0.84	-	0.69
T_6	Soybean - Onion	0.48	0.88	-	0.71
T_7	Soybean - Potato - Onion	0.51	0.93	0.82	0.88
T_8	Soybean - Garden pea - Garlic	0.48	0.91	0.74	0.82
T_9	Soybean - Wheat *aestivum*	0.44	0.73	-	0.64
T_{10}	Soybean - Wheat *durum*	0.44	0.77	-	0.66
T_{11}	Soybean - Chickpea *desi*	0.43	0.38	-	0.52
T_{12}	Soybean - Chickpea *Kabuli*	0.46	0.44	-	0.54
T_{13}	Soybean - Garlic	0.47	0.86	-	0.72
T_{14}	Soybean - Onion	0.48	0.90	-	0.74
T_{15}	Soybean - Potato - Onion	0.54	0.95	0.85	0.91
T_{16}	Soybean - Garden pea - Garlic	0.49	0.92	0.77	0.86

onion T_7 with SEYs (173.18 q/ha), production efficiency (56.40 q/ha), use efficiency of land (83.84%) and sustainable yield index (0.88) while the minimum soybean equivalent yield (42.79 q/ha) with production efficiency (22.93 kg/ha/day), use efficiency of land (56.30%) and sustainable yield index (0.50) was recorded under existing crop sequence soybean - chickpea *desi* T_3 system.

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