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On-farm evaluation of performance of soybean-maize sequence *vis-a-vis* maize-maize cropping system under medium black soils of Telangana

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Abstract
Crop diversification with resource efficient and remunerative cropping systems is a sustainable agricultural practice. On farm evaluation with diversified cropping system of soybean-maize *vis-a-vis* farmers' practice of maize-maize was conducted in ten farmer's fields of Warangal district of Telangana state. Crop diversification with soybean-maize realized 7% higher mean maize grain equivalent yield (12302 kg ha^{-1}) over farmer's practice of cultivation of maize-maize (11492 kg ha^{-1}) with a mean gain of 810 kg ha^{-1}. Mean technology and extension gaps were 698 kg ha^{-1} and 810 kg ha^{-1} respectively. Technology index ranged from 0.7 to 12.4% with an average value of 5.4%. The mean gross and net returns of diversified cropping system were Rs.141471 and 68941 ha^{-1}, while that of farmers practice were Rs 132158 and 55693 ha^{-1} respectively. On an average a B C ratio of 2.0 was earned in improved cropping system as against the 1.7 under farmers practice. The mean additional returns in improved cropping system were Rs 9313 ha^{-1} with a mean effective gain of Rs 13249 ha^{-1}. Improved cropping systems registered a mean total productivity per day of 33.7 kg ha^{-1} day^{-1} with a mean profitability of Rs 189 day^{-1}. Average Production Use Efficiency of improved cropping system was 61.5 kg ha^{-1} day^{-1}, while that of farmer's practice was 57.5 kg ha^{-1} day^{-1}. The edge in productive economic parameters in terms of Mean Relative Productive Use Efficiency and Relative Economic Efficiency were 7.0 and 23.8 respectively and were indicating the profitability of diversified cropping system.

Keywords: Crop diversification, soybean-maize, maize-maize, maize equivalent yield, technology gap, technology index, production efficiency, economic efficiency

Introduction
Maize is the one of the principal crops in Telangana state grown in 5.73 lakh ha with a production of 17.51 lakh tonnes and productivity of 3057 kg ha^{-1} (Telangana Directorate of Economics and Statistics, 2017) [25]. Warangal is one of the maize growing districts of the state, with 0.75 lakh hectares of area. The crop is grown on diverse kinds of soils varying from medium black soils to light red soils. Majority of the crop in the state is grown as rainfed under low fertile soils while under irrigated situations, two crops of maize are grown in sequence per year. Maize being an exhaustive crop, mono-cropping of the crop threatens the soil sustainability. Further due to resurgence of pests and diseases particularly the post flowering stalk rots drastic losses yield were common. Under such circumstances, diversifying cropping systems by increasing the spatial and temporal heterogeneity of agricultural mosaics might be a feasible alternative to overcome the negative effects of modern agriculture (Burel *et al.*, 2013) [3]. Further, ignoring of pulses in cropping pattern and dwindling of cattle population is leading to exhaustion of soil organic matter making the soil ecosystem more fragile with low moisture retentivity and poor fertility. Unfortunately legume incorporation in the soil has been slowly eliminated from cropping systems, and has led to serious consequences on soil fertility. Despite their great potential for making significant N contributions and improving productivity, the adoption of legumes is poor due to wide range of socio economic and physical constraints (Shah *et al.*, 2003; Chikowo *et al.*, 2006; Ojiem *et al.*, 2006) [23, 6, 16]. Cultivation of legumes for seed, fodder or green manure can positively influence the structure and functioning of the agro-ecosystem (Pierce and Rice, 1988) [18]. Studies have shown that crop yield and product quality are usually improved when legume are grown as a preceding crop (Campiglia *et al.*, 1999) [4] in any cropping sequence.
Crop rotation with legumes improves soil properties (Bagayako *et al.*, 2000; Chan, and Heenan, 1996; Giller, 2001; Yusuf, etal., 2009) [1, 5, 8, 26]. And might therefore reduce mineral fertilizer requirements of succeeding non leguminous crops. Crop rotation also influences N use efficiency and prompt changes in various N sources, affecting availability to the plant

(Lopez and Lopez, 2001.) [12] Legumes are known to increase soil N levels (National Academy of Science, 1979; Ladd *et al*. 1981; Reddy *et al*. 1986) [15, 11, 20]. Consequently they improve the productivity of subsequent cereal crops (Singh and Awasthi 1978) [24]. Though legume materials contribute only a small portion of the available N pool, their main value appears to be long term, i.e., in their capacity to maintain or increase concentrations of soil organic N to be decomposed at relatively slow rates in the following years (Ladd *et al*. 1981) [11]. Canavalia ensiformis, Mucuna pruriens, Glycine max, and Vigna unguiculata have been reported to potentially contribute considerable amounts of N to succeeding crops (Sanginga, *et al*., 1996; Ravuri and Hume 1992; Mughogho, *et al*., 1982.) [22, 19, 14]

Soybean (*Glycine max* L.) is a dual purpose most important rainy season crop to meet pulse and oil requirements. It is also highly adaptable to varying soil and climatic conditions, giving fairly high yields compared to other pulse crops (Padhi and Panigrahi, 2006) [17]. Soybean being a short duration (85 to 130 days depending on the latitude) leguminous energy rich crop, offers good potential to get involved in the cropping sequences or intercropping systems. The crop is relatively tolerant to drought, excessive moisture, low pH and high aluminum content (Billore, 2014) [2]. Further its cultivation does not cause any allelopathic effect on companion/succeeding crops, extends benefits of 45 to 60 kg residual nitrogen per hectare to the succeeding crop and creates salutary physio-chemical environment in the soil for crop growth (Kumar *et al.*, 2012) [10]. Soybean due to its trade and industrial significance and adaptability to varied agro-climatic conditions occupies greater part of potential cultivated area as an integral part of prevailing cropping systems in India and world over.

In Telanagana state, at present soybean is cultivated over 0.24 million hectares with an annual production of 0.25 million tones and productivity of 1036 kg ha^{-1} (Telangana Directorate of Economics and Statistics, 2017) [25]. However, productivity of soybean can further be increased by including in the cropping sequences as intercrop or as sequence crop. Area under soybean is increasing enormously in Northern parts of Telangana state due to better yield potential and market price. Keeping in view of the above, soybean-maize sequence is evolved as an alternative sustainable and climate smart cropping system to maize-maize in medium black soils.

Materials and Methods

To study and demonstrate the production potential of improved cropping system of soybean followed by maize in comparison with farmer's practice of maize-maize, front line demonstrations were conducted during the year 2016-17 in 10 locations (irrigated and medium back soils) of Warangal district by On Farm Research Centre, All India Coordinate Research Project on Integrated Farming Systems. An area of 0.4 ha per each location was chosen for study. The variety JS-335 of soybean and popular private hybrids for maize were used in the study. JS 335 variety of soybean has yield potential of 20-25 q ha^{-1} and comes to maturity in 90-95 days. Private hybrids of maize with 90 days duration and yield potential of 60-70 q ha^{-1} were selected. Cultivation of maize-maize (farmer's practice) was considered as control. Sowing of crops in both the treatments during *kharif* season were done during June 3rd week to 10th July 2017. Whereas Rabi crops soybean and maize were sown during October 2nd week to November 1st week. Recommended spacing was adopted for soybean (45 X 5 cm) and maize (60 X 20 cm). A seed rate of 70 kg ha^{-1} and 8 kg ha^{-1} was adopted for soybean and maize respectively. Seed treatment with thiram @ 3 g /kg of seed followed by 5ml of imidacloprid /kg of seed to prevent pest and diseases. All management practices for weed, nutrient, pest and diseases were adopted as per the recommendations of PJTSAU. A rainfall of 990 mm was received in 65 rainy days and the crop was maintained rainfed during *kharif* season and 6 numbers of irrigations provided during Rabi season. The data on grain yield was collected by random crop cutting method and the yield of boh the crops was presented as maize grain equivalent yield. It was calculated by converting the seed yield of soybean into maize equivalent yield on the basis of sale price of soybean.

$$\text{Maize Equivalent Yield} = \frac{\text{(Soybean grain yield (kg ha}^{-1}\text{) x Price of soybean (Rs kg}^{-1}\text{)}}{\text{Maize grain price (Rs/kg)}}$$

Paired T test was employed to test the efficiency of improved cropping system over farmers practice. Benefit Cost ratio, gross and net returns were calculated based on grain yield and prevailing market price. Per day net returns were worked out by dividing total net returns with the duration of the crop.

The extension gap, technology gap and technology index were calculated as per the following formula drawn by Samui *et al.* (2000).

Extension gap= Yield of Improved practice- Yield of farmers practice.

Technology gap= Potential yield –yield of improved practice

$$\text{Technology index} = \frac{\text{Technology gap}}{\text{Potential yield}} \text{ X } 100$$

Production and Economic indices are calculated based on following formulae.

Additional Returns=Extension gap X Sale price

Effective gain = Additional returns – Additional cost

Returns per rupee investment (Rs Re^{-1}) = Net Returns/Cost of Cultivation

Per day Productivity (kg ha^{-1} day^{-1}) = Total productivity/365

Per day Profitability (Rs ha^{-1} day^{-1}) = Total profitability/365

Production Use Efficiency is efficiency measured in terms of yield/day

Production Use Efficiency (kg ha^{-1} day^{-1}) =

$$\frac{\text{Total grain yield of a system}}{\text{Period in days consumed to produce the yield}}$$

Relative Productive Use Efficiency (%)

$$= \frac{\text{Total Productivity in diversified cropping system} - \text{Total productivity in existing cropping system}}{\text{Total productivity in existing cropping system}} \text{ X } 100$$

Relative Economic Efficiency (%)

$$= \frac{\text{Net Returns of diversified cropping system} - \text{Net Returns of existing cropping system}}{\text{Net Returns of existing cropping system}} \text{ X } 100$$

Results and Discussion

Grain yield

The Maize Grain Equivalent Yield (MGEY) of diversified cropping system of soybean - maize was ranging from 11394 kg ha^{-1} to 12914 kg ha^{-1} across the locations and was 4.6 to 7.4% higher than of maize-maize system (farmers' practice) yields (10885 kg ha^{-1} to 12015 kg ha^{-1}). Mean MGEY of improved cropping system (Table 1) of soybean - maize was 7% higher (12302 kg ha^{-1}) than grain yield in farmers practice of maize-maize system (11492 kg ha^{-1}). The mean gain of maize grain equivalent yield was significantly greater than zero (Mean =810, SD =444, N= 10) with a *t* stat value of 5.77and two-tail p value of 0.000269, providing evidence that the improved cropping system is efficient than farmers practice. Legumes are noteworthy for their nitrogen fixation, particularly soybeans have symbiotic nitrogen-fixing bacteria in root nodules. The crop fixes atmospheric nitrogen in soil. Thus preceding soybean in soybean-maize system might have sustained the organic matter content through litter fall and leaf biomass and thereby enhanced the biological activity in turn soil fertility and nutrient availability to succeeding maize and resulting in increased yield of maize in soybean-maize system than maize-maize system. Munyinda *et al*. (1988) [9] also reported higher wheat grain yield in soybean-wheat system than other systems like maize-wheat. Reddy *et al*. (1986) [20] and Singh and Awasthi (1978) [24] also reported similar results for rye, maize and wheat, which produced higher yields following tropical legumes than cereals.

Economics

Diversified cropping system of soybean - maize earned gross returns ranging from Rs. 1, 31, 030 to Rs 1, 48, 510/- across the locations. While gross returns of maize-maize under farmers practice ranged from Rs. 1, 25, 177 to Rs 1, 38, 173/- (Table 2). The mean gross returns under improved cropping systems were Rs 1, 41, 471 *vis-a-vis* Rs 1, 32, 158/- in farmers' practice. The mean gain of net return was Rs 9,313 with standard deviation of 5104 and was significant over farmers' practice. Net returns in improved cropping systems ranged from Rs.60,330 to Rs.77, 960 with mean value of Rs 68, 941 while net returns of farmers practice of maize-maize system varied from Rs 51, 028 to Rs 62, 573 with an average net returns of Rs 55, 693/-. The returns on earned per rupee investment were ranging from Rs 1.8 to Rs 2.1 with mean BC ratio of Rs 2.0 in improved cropping system, where as in farmers practice the benefit was Rs 1.7-1.8 per rupee cost with mean value of 1.7. Per day returns ranged from Rs. 302 to Rs.390 in improved cropping system with as an average of Rs 345. While maize-maize system resulted in Rs 255 to 313 per day returns with mean of Rs 278. Higher economics in improved cropping systems over farmers' practice can be attributed to higher Maize grain equivalent yield, high gross and net returns and lower cost of cultivation.

These findings are also in agreement with the results of Malik *et al.* (1991) [13] who reported residual effect of legumes such as pigeonpea, mungbean and cowpea on cereals (maize and wheat) and found increasing monetary returns. Gadgil *et al.* (2002) [7] reported that high benefit cost ratio and effective net returns can be obtained with the introduction of legume based cropping patterns.

Technology gap, Extension gap and Technology Index

Technology gap ranged from 86 kg ha^{-1} to 1867 kg ha^{-1} with a mean of 698 kg ha^{-1}. Whereas extension gap varied from 194 to 1508 kg ha^{-1}with average value of 810 kg ha^{-1} (Table 1). Technology index represents the feasible adaptability improved cropping systems from lab to land. Lower the technology index means more viability of innovative cropping system at farmer's field. Thus attaining higher yields almost close to potential yields will hasten up the adoption of improved cropping system interventions to increase the yield performance. The technology index in the current study ranged from 0.7 to 12.4% with an average value of 5.2%.

Production and economy indices

Additional returns in diversified cropping system ranged from Rs. 2230 to 17340 ha^{-1} with mean additional returns of Rs 9313 ha^{-1} (Table 3). Effective gain in improved cropping system ranged from Rs 6930 ha^{-1} to Rs 21640 ha^{-1} with an of Rs 13249 ha^{-1}. Total per day productivity in improved cropping systems varied from 31.2 kg to 35.4 kg ha^{-1} day^{-1} with mean of 33.7 kg ha^{-1} day^{-1}as against 31.8 kg ha^{-1} day^{-1} in farmers practice which ranged from 29.8 to 32.9 kg ha^{-1} day^{-1}. Mean per day profitability of diversified cropping system was Rs 189 and was ranging from Rs 165 to Rs 214/-.

Production Use Efficiency of diversified soybean-maize system ranged from 57.0 to 64.6 kg ha^{-1} day^{-1} with an average of 61.5 kg ha^{-1} day^{-1}, while it was 54.4 to 60.1 kg ha^{-1} day^{-1} with mean of 57.5 in maize-maize system. Relative Productive Use Efficiency of soybean-maize system shoot up to 13.4% with an average of 7.0% whereas Mean Relative Economic Efficiency was 23.8% and it ranged from 11.5 to 40.7%.

Table 1: Grain yield, Technology gap, Extension gap and Technology Index of improved cropping system *vis–a-vis* farmers' practice

Trial No	Grain yield (kg ha^{-1}) in Improved (soybean-maize) cropping systems		Maize Equivalent Yield (kg ha^{-1} in Improved system	Maize yield in farmers practice (maize-maize) (kg ha^{-1})			Maize Gain Equivalent Yield (kg ha^{-1})	Potential yield (kg ha^{-1}) of Improved system	% increase in yield over farmers practice	Technology gap (kg ha^{-1})	Extension gap (kg ha^{-1})	Technology Index
	Soybean	Maize		kharif	Rabi	Total						
1	2115	6650	12167	5650	6250	11900	267	13000	2.2	833	267	6.4
2	2175	5720	11394	5720	5480	11200	194	13000	1.7	1867	194	12.4
3	2300	6100	12100	5040	5845	10885	1215	13000	11.2	900	1215	6.9
4	2150	6060	11669	5680	5460	11140	529	13000	4.7	1331	529	10.2
5	2305	5965	11978	5850	5465	11315	663	13000	5.9	1022	663	7.9
6	2280	6805	12753	5740	5505	11245	1508	13000	13.4	247	1508	1.9
7	2150	6795	12404	6050	5845	11895	509	13000	4.3	596	509	4.6
8	2295	6835	12822	5970	5635	11605	1217	13000	12.7	178	1478	1.4
9	2290	6940	12914	6070	5945	12015	899	13000	9.7	86	1160	0.7
10	2280	6870	12818	5750	5970	11720	1098	13000	9.4	182	1098	1.4
Mean	2234	6474	12302	5752	5740	11492	810	13000	7.0	698	810	5.4
Std. Dev							444					
t statistic							5.77					
Two-tail *p*-value							0.000269					

Table 2: Economics of improved cropping system *Vis –a-Vis* farmers' practice.

Trial No	Cost of Cultivation (Rs ha^{-1})		Gross Returns (Rs ha^{-1})			Net Returns (Rs ha^{-1})		B: C ratio		Per day Net Returns (Rs ha^{-1})	
	Improved system	Farmers Practice	Improved system	Farmers Practice	Gain	Improved system	Farmers Practice	Improved system	Farmers Practice	Improved system	Farmers Practice
1	74300	78000	139925	136850	3075	65625	58850	1.9	1.8	328	294
2	70700	75400	131030	128800	2230	60330	53400	1.9	1.7	302	267
3	71100	74150	139150	125177	13973	68050	51028	2.0	1.7	340	255
4	73800	74780	134190	128110	6080	60390	53330	1.8	1.7	302	267
5	71400	77225	137748	130123	7625	66348	52898	1.9	1.7	332	264
6	71900	76200	146658	129318	17340	74758	53118	2.0	1.7	374	266
7	74000	77650	142643	136793	5850	68643	59143	1.9	1.8	343	296
8	74200	77750	147453	133458	13995	73253	55708	2.0	1.7	366	279
9	70550	75600	148510	138173	10338	77960	62573	2.1	1.8	390	313
10	73350	77900	147405	134780	12625	74055	56880	2.0	1.7	370	284
Mean	72530	76466	141471	132158	9313	68941	55693	2.0	1.7	345	278
Std dev					5104						

Table 3: Production and Economic indices of improved cropping system *Vis –a-Vis* farmers' practice.

Trial No	Additiona Returns (Rs ha^{-1})	Effective gain (Rs ha^{1})	Per day productivity (kg ha^{-1} day^{-1})		Per day Profitability (Rs ha^{-1} day^{-1})	Production Use Efficiency (kg ha^{-1} day^{-1})		Relative Productive Use Efficiency (%)	Relative Economic Efficiency (%)
			Improved system	Farmers Practice		Improved system	Farmers Practice		
1	3075	6775	33.3	32.6	180	60.8	59.5	2.2	11.5
2	2230	6930	31.2	30.7	165	57.0	56.0	1.7	13.0
3	13973	17023	33.2	29.8	186	60.5	54.4	11.2	33.4
4	6080	7060	32.0	30.5	165	58.3	55.7	4.7	13.2
5	7625	13450	32.8	31.0	182	59.9	56.6	5.9	25.4
6	17340	21640	34.9	30.8	205	63.8	56.2	13.4	40.7
7	5850	9500	34.0	32.6	188	62.0	59.5	4.3	16.1
8	13995	17545	35.1	31.8	201	64.1	58.0	10.5	31.5
9	10338	15388	35.4	32.9	214	64.6	60.1	7.5	24.6
10	12625	17175	35.1	32.1	203	64.1	58.6	9.4	30.2
Mean	9313	13249	33.7	31.5	189	61.5	57.5	7.0	23.8

Conclusion

Results obtained from computation of indices, yield and returns showed a significant advantage of diversifying the system with soybean – maize sequence crop rather than mono-cropping of maize-maize system in medium black soils of Telangana state.

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