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Conservation agriculture practices improves productivity and sustainability of peanut (*Arachis hypogaea*)-based cropping systems

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ABSTRACT

To assess the influence of conservation agriculture (CA) practices on productivity and sustainability of peanut (*Arachis hypogaea* L.) - based cropping systems, the present field experiment was conducted for five consecutive years (2011–12 to 2015–16) at Junagadh, Gujarat, India. The experiment, comprising 14 treatments, viz. sole peanut, peanut-*Sesbania*, peanut-green gram (GG), peanut-conventional tilled wheat (CTW), peanut-CTW-*Sesbania*, peanut-CTW-GG, peanut-CTW-wheat straw incorporation (WSI), peanut-zero tilled wheat (ZTW), peanut-ZTW-*Sesbania*, peanut-ZTW-GG, peanut-ZTW-WSI, peanut+pigeonpea, peanut+pigeonpea-*Sesbania* and peanut+pigeonpea-GG was laid out in randomized block design with three replications at fixed site. Peanut -CTW-*Sesbania* cropping system (2.94 t/ha) recorded maximum pod yield of peanut while haulm yield was higher under peanut-ZTW-*Sesbania* (3.24 t/ha). Green manuring with *Sesbania* in peanut-ZTW and peanut+pigeonpea recorded higher grain yield of wheat (2.91 t/ha) and sud yield of pigeonpea (1.93 t/ha), respectively. System productivity (4.55 t/ha) was significantly higher under peanut-ZTW-*Sesbania* cropping system over sole peanut (with or without GM), peanut-CTW/ZTW, peanut-ZTW-WSI and peanut+pigeonpea (with or without GM). Peanut-ZTW-*Sesbania* also recorded maximum sustainable yield index (0.46) and sustainable value index (0.48) than other cropping systems. Thus, peanut followed by ZTW or CTW and GM was more productive and sustainable than sole peanut.

Key words: Conservation agriculture practices, Peanut-based cropping systems, Sustainability indices, System productivity

In India, peanut (*Arachis hypogaea* L.) is cultivated on an area of 5.34 million ha with production of 7.46 million tonnes and productivity of 1.4 tonnes/ha (DES 2019). As pods developed below the ground, the whole plant is to be uprooted. Thus, the peanut crop removes both above-and-below ground biomass and thereby affects soil organic C negatively. Declining soil organic matter and soil carbon on regular basis may be attributed to continuous peanut cultivation which showed its effect on soil health, quality and productivity (Tojo Soler *et al*. 2011, Srinivasa rao *et al*. 2012). Due to uprooting of peanut, soil gets loosened. Farmers still plough down the field 2–3 times to cultivate the succeeding *rabi* crops that increases cost of cultivation. Under such conditions, cultivation of wheat without disturbing the soil, can be an alternate to reduce cost of cultivation and obtaining at par or even higher yield than conventionally grown wheat. The benefits of zero tillage is more pronounced during *rabi* owing to lesser weed infestation and assured irrigation (Choudhary *et al*. 2017).

Surface retention of adequate crop residues, an important component of CA, is a challenge in the livestock based agrarian economy where crop straw and fodder are used as animal feed. It is known that application of organic manures provides a balance supply of nutrients and enhances soil organic matter. But owing to scarcity of other organic forms now-a-days, green manures remain the only economical alternative. The green manuring has been known to reduce soil *p*H and nutrient losses, improves soil structure, porosity, soil fertility, water holding capacity and partly reduces nitrogen demand for the succeeding crop (Buttar and Rana 2014, Sharma *et al*. 2014). Intercropping of short duration crops in inter space between two rows of a widely spaced crops like pigeonpea, can help in better resource utilization, soil cover and stabilise crop productivity (Sharma *et al*. 2010). Since very limited information is available on effect of CA practices (cropping system, zero tillage, GM) on productivity and sustainability of peanut-based cropping system in Saurashtra region of Gujarat, hence the present investigation was undertaken.

MATERIALS AND METHODS

The field experiment was conducted at ICAR-Directorate of Groundnut Research, Junagadh (Gujarat), India for five consecutive years during 2011–12 to 2015–16.

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The site was located at a latitude of $21^0 31'$ N and longitude 70^0 26' E with an elevation of about 60 m MSL. The soil of the experimental site was Typic haplustepts (USDA soil classification) which is underneath by meliolitic limestone having high clay content (52-55%). The soil was alkaline in reaction (*p*H 8.12), shallow to medium in depth, medium black in colour, slightly calcareous (4-8% $CaCO_3$) and low in available nitrogen (104.2 kg/ha), medium in phosphorus (13.5 kg/ha) and potassium (289.1 kg/ha). The experiment, comprised 14 treatments, viz. sole peanut (Pn), peanut-*Sesbania* (Se), peanut-green gram (GG), peanut-conventional tilled wheat (CTW), peanut-CTW-*Sesbania*, peanut-CTW-GG, peanut-CTW-wheat straw incorporation (WSI), peanut-zero tilled wheat (ZTW), peanut-ZTW-*Sesbania*, peanut-ZTW-GG, peanut-ZTW-WSI, peanut+pigeonpea, peanut+pigeonpea-*Sesbania* and peanut+pigeonpea-GG was laid out in randomized block design with three replications in plot size of 5 m × 6.3 m at a fixed site. Findings are being discussed based on effect of treatments on four years of investigation (2012–16) as in the first cycle (2011-12), all 14 treatment combinations were applied to peanut-based cropping systems.

The experimental field was prepared with cultivator followed by harrowing and planking once during *kharif* for peanut and pigeonpea. Peanut TG 37A was sown from second fortnight of June to first week of July using seed rate of 100 kg/ha with spacing 30 cm × 10 cm and was harvested on first/second fortnight of October. The crop was fertilized with 25 kg N, 22 kg P and 24.9 kg K/ha at the time of sowing. In peanut+pigeonpea intercropping system (3:1), after every third row of peanut, a row of pigeonpea BDN 2 was sown in replacement series using 7.5 kg/ha seed rate, and fertilizers @ 10 kg N, 11 kg N and 12.5 kg K/ha at the time of sowing. Pigeonpea pods were picked from second fortnight of November to first week of March. In intercropping, seed and fertilizers in peanut were applied on the basis of number of rows in each plot. After harvesting of peanut, wheat was sown during *rabi* season in the same field as per treatment with seed cum fertilizer drill for conventional tilled plots, and zero till seed-cum-fertilizer drill was used in zero-tilled plots. Wheat 'GW 366' was sown during second fortnight of November using 100 kg/ha seed and fertilizers @ 100 kg N, 22 kg P and 24.9 kg K/ha. Half dose of N and full doses of P and K were applied at the time of sowing, and remaining half N in two splits at 20 and 40 days after sowing (DAS). The wheat straw was recycled as per treatments, and irrigation was done in these plots for easy decomposition. In the summer season, the same field was pre-irrigated in the first to second week of March and ploughed twice, followed by harrowing and planking. Thereafter, green manure crops i.e. green gram and *Sesbania aculeata* (Local) were sown *in situ* using 50 and 40 kg/ha seed rate, respectively and were fertilized with 20 kg N, 17.6 kg P and 24.9 kg K/ha. Both the crops were ploughed down at 45–50 DAS using disc plough. Besides these, other recommended package of practices were adopted to raise the crops.

The plant height and biomass production was recorded from three randomly selected plants from each plot at harvest of peanut. Yield attributes, viz. number and weight of mature pods/plant, 100-kernel weight and shelling out-turn in peanut were also recorded at harvest. At physiological stage of maturity, peanut plants were uprooted manually and sundried for 4-5 days and weighed to record biomass yield. Pods were threshed to record weight and expressed as t/ha. Pigeonpea plant samples were analysed for biomass production, seed and stalk yields. The wheat samples were analysed for plant height, biomass production, number of total and effective tillers/m row length, spikelets/spike, spike length, grains/spike, test weight, grain and straw yields.

The productivity of different cropping systems was computed by converting yields of pigeonpea and wheat into system productivity, expressed in terms of peanut-pod equivalent yield (PPEY) based on the prevailing market/minimum support price (Sarma 2014). Sustainability indices, viz. sustainable yield index (SYI) and sustainable value index (SVI) were also calculated over a period of four years for different treatments using formula suggested by Singh *et al*. (1990). Statistical analysis of data was performed online on Indian NARS Statistical Computing Portal (http://stat.iasri.res.in/sscnarsportal) using General Linear Model (GLM) procedure in SAS (SAS Institute Inc.). For significant parameters, separation of treatment means and ranking of treatments was done using the Tukey's Honest Significant Difference Test at P=0.05.

RESULTS AND DISCUSSION

Peanut: Peanut plants under peanut-ZTW-*Sesbania* cropping system were significantly taller (30.8 cm) than sole peanut and peanut-ZTW (Table 1). Similarly, peanut-CTW/ZTW-*Sesbania* recorded maximum peanut biomass production (11.8 g/plant) which was significantly higher over peanut+pigeonpea and peanut+pigeonpea-*Sesbania* by 25.5 and 21.4%, respectively (Table 1). The highest number and weight of mature pods/plant were recorded under peanut-CTW-*Sesbania* which was significantly higher in comparison to sole peanut, peanut-*Sesbania*, peanut-GG, peanut-ZTW, peanut-ZTW-WSI and peanut+pigeonpea with or without GM in case of number of mature pods/plant and over sole peanut, peanut+pigeonpea, and peanut+pigeonpea-*Sesbania* for weight of mature pods/plant. The present finding was quite similar with those of Yadav *et al*. (2018). On the other hand, 100-kernel weight was significantly more under peanut-ZTW-*Sesbania* over peanut-GG, peanut-CTW, peanut-CTW-GG, peanut-ZTW-WSI and peanut+pigeonpea cropping systems and was at par with other cropping systems. However, maximum shelling out-turn was recorded under peanut-GG and was at par with sole peanut, peanut-*Sesbania*, peanut-ZTW, peanut-ZTW –GG and peanut + pigeonpea with or without GM.

Pod yield of peanut was recorded maximum in peanut-CTW-*Sesbania* cropping system (2.94 t/ha) which was significantly higher compared to sole peanut and peanut+pigeonpea with or without GM by 12.8–74.9%,

Table 1 Influence of conservation agriculture practices and cropping systems on growth, yield and sustainability of peanut-based cropping systems (mean data of 4 years)

Treatment	Peanut						Wheat								Pigeonpea			Peanut-based cropping systems		
	Plant height (cm)	Biomass production (g/plant)	Mature pods/plant (No.)	Mature pods/plant (g)	100-kernel weight (g)	Shelling out-turn (%)	Plant height (cm)	Biomass production (g/plant)	Total tillers/m row (No.)	Effective tillers/m row (No.)	Spike length (cm)	Spikelet/ spike	Grains/ spike	Test weight (g)	Biomass production (g/plant)	Seed yield (t/ha)	Stalk yield (t/ha)	System productivity (t/ha)	SYI*	SVI
Sole peanut	27.6$^{B\#}$	10.3$^{ABC\#}$	13.36$^{D\#}$	11.26$^{BC\#}$	33.51$^{ABCD\#}$	63.8^{A}												2.60$^{E\#}$	0.15	0.10
Peanut-*Sesbania*	30.3^{AB}	11.2^{ABC}	13.72^{BCD}	12.39^{AB}	33.11^{ABCD}	62.3^{BC}												2.90^{E}	0.18	0.12
Peanut-GG	30.1^{AB}	11.6^{A}	13.82^{BCD}	12.88^{AB}	32.94^{BCD}	64.5^{A}												2.85^{E}	0.21	0.15
Peanut-CTW	29.4^{AB}	10.7^{AB}	14.92^{AB}	12.69^{AB}	32.54^{BCD}	60.6^{C}	54.7$^{E\#}$	2.00$^{C\#}$	106.8$^{B\#}$	96.4	6.61	11.8	32.6$^{D\#}$	44.0				4.21^{ABC}	0.38	0.37
Peanut-CTW-*Sesbania*	29.6^{AB}	11.8^{A}	15.79^{A}	13.51^{A}	34.29^{ABC}	60.4^{C}	58.5^{BC}	2.41^{B}	110.4^{AB}	100.9	6.79	12.1	37.0^{BC}	44.2				4.49^{A}	0.41	0.38
Peanut-CTW-GG	29.5^{AB}	11.5^{A}	15.31^{ABC}	13.40^{A}	33.11^{ABCD}	63.7^{AB}	60.7^{B}	2.21^{B}	115.2^{A}	102.8	6.68	12.0	35.5^{BC}	44.5				4.28^{ABC}	0.44	0.42
Peanut-CTW-WSI	29.1^{AB}	11.0^{A}	15.16^{A}	12.38^{A}	34.83^{AB}	60.9^{C}	55.6^{DE}	2.33^{B}	110.6^{AB}	100.7	6.57	11.4	34.4^{CD}	44.3				4.29^{ABC}	0.40	0.41
Peanut-ZTW	28.3^{B}	10.9^{AB}	13.78^{BCD}	12.11^{ABC}	34.23^{ABC}	64.1^{A}	59.0^{BC}	2.29^{AB}	115.1^{A}	104.5	6.78	12.3	38.2^{AB}	44.3				4.25^{ABC}	0.44	0.47
Peanut-ZTW - *Sesbania*	30.8^{A}	11.8^{A}	15.61^{A}	13.33^{A}	34.97^{A}	62.4^{B}	66.2^{A}	2.51^{A}	116.3^{A}	107.5	6.49	12.4	39.1^{A}	46.9				4.55^{A}	0.46	0.48
Peanut-ZTW – GG	29.0^{AB}	11.1^{A}	15.42^{ABC}	13.04^{A}	33.45^{ABCD}	63.8^{AB}	57.5^{CD}	2.10^{BC}	113.3^{AB}	103.8	6.67	12.3	36.3^{BC}	45.1				4.33^{A}	0.44	0.44
Peanut-ZTW-WSI	28.8^{AB}	10.6^{ABC}	14.18^{CD}	12.75^{AB}	31.94^{CD}	62.5^{B}	56.5^{CDE}	2.12^{BC}	115.4^{A}	101.6	6.79	12.3	37.3^{ABC}	44.4				4.13^{ABC}	0.40	0.42
Peanut + pigeonpea	29.9^{AB}	9.4^{C}	12.44^{D}	10.28^{C}	32.45^{D}	63.7^{AB}									297.8$^{B\#}$	1.78$^{B\#}$	6.16	3.92^{D}	0.37	0.40
Peanut + pigeonpea -*Sesbania*	29.8^{AB}	9.7^{BC}	12.67^{D}	11.38^{C}	34.45^{AB}	63.9^{AB}									318.4^{A}	1.93^{A}	6.28	4.05^{BCD}	0.37	0.37
Peanut + pigeonpea –GG	30.6^{AB}	10.4^{ABC}	13.39^{D}	13.02^{A}	34.41^{ABC}	64.3^{A}									304.8^{A}	1.85^{A}	6.12	3.98^{C}	0.36	0.35

$^{\#}$Means within the same column followed by superscripted different uppercase letter(s) are statistically different using Tukey's Honest Significant Difference Test at $P<0.05$. *Calculated on the basis of system productivity; SYI: Sustainable yield index; SVI: Sustainable value index

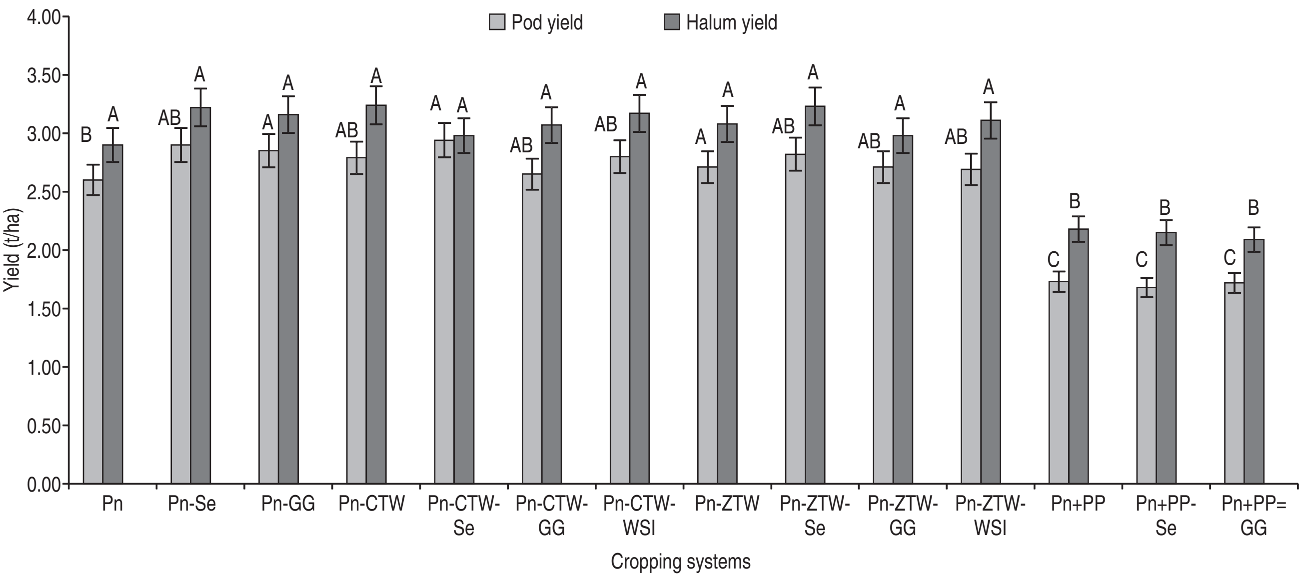

Fig 1 Peanut yield as influenced by conservation agriculture practices. Pn, sole peanut; PP, pigeonpea; GG, green gram; Se, *Sesbani*a; CTW, conventional tilled wheat; ZTW, zero tilled wheat; WSI, wheat straw incorporation. Vertical bars represent the standard error (P=0.05). Means within the same column followed by superscripted different uppercase letter(s) are statistically different using Tukey's Honest Significant Difference Test at P< P0.05.

respectively (Fig 1). On the other hand, peanut-CTW cropping system registered maximum haulm yield of peanut (3.24 t/ha) which was significantly higher compared to peanut+pigeonpea with or without GM by 87.8–93.1% (Fig 1). The increase in biomass production was probably due to residual effect of biological N fixed in the root nodules of previous green manure crop (*Sesbania*). Legume green manuring increased the availability of N in balanced form along with other nutrients which resulted in significant improvement in peanut dry matter production (Jat *et al*. 2011). These observations agreed with the findings of Jain *et al*. (2018) and Yadav *et al.* (2018). Pod and haulm yields were significantly lower in all the peanut intercropping systems than other peanut-based cropping systems (Fig 1) probably due to lower plant population of peanut, and presence of competition between main crop (peanut) and the intercrop (pigeonpea) for growth resources such as nutrients, moisture and solar radiation (Moriri *et al*. 2010).

Wheat: Significantly taller wheat plants were reported under peanut-ZTW-*Sesbania* (66.2 cm) over all cropping systems (Table 1). Similarly, maximum biomass production and total tillers/m row length were recorded under peanut-ZTW-*Sesbania*. However, other yield attributes, viz. effective tillers/m row length, spike length, spikelets/spike and test weight of wheat did not differ significantly due to tillage, straw incorporation and GM. Number of grains/spike were significantly higher in peanut-ZTW-*Sesbania* over other cropping systems except peanut-ZTW and peanut-ZTW-WSI. The grain yield of wheat was also recorded maximum (2.91 t/ha) under peanut-ZTW-*Sesbania* which was significantly higher over peanut-CTW, peanut-CTW-*Sesbania* and peanut-CTW/ZTW-WSI (Fig 2). However, straw yield did not differ significantly due to various treatments. Among tillage methods, ZTW recorded about 4.8% higher grain yield over CTW raised with or without GM or WSI. Singh *et al*. (2014) and Jat *et al*. (2019) noticed similar findings that the practice of ZT was found to increase the grain yield of wheat under rice-wheat cropping system significantly over CT practice at different locations. Green manuring had compounded effect on grain yield of wheat due to additional N supply and improved soil environment (Singh and Shivay 2013). However, straw yield of wheat was not affected significantly with different tillage practices.

Pigeonpea: Peanut+pigeonpea-*Sesbania* cropping system produced significantly higher biomass production (318.4 g/plant) and seed yield (1.93 t/ha) of pigeonpea by 6.9 and 8.9%, respectively in comparison to peanut+pigeonpea (Table 1). However, stalk yield did not show any perceptible variation due to GM with *Sesbania* or GG. Use of legume as GM to enhance soil productivity has been traced back to the days of Cato (234-149 BC) as they fix atmospheric nitrogen in the root nodules through symbiotic association with *Rhizobium* bacterium and leave part of it for utilization for the companion or succeeding crop (Butter and Rana 2014). Jat *et al*. (2011) also reported similar findings.

System Productivity (*Peanut-pod equivalent yield*): Peanut-ZTW-*Sesbania* cropping system produced significantly higher system productivity, expressed in terms of peanut-pod equivalent yield (4.55 t/ha) compared to sole peanut and peanut+pigeonpea with or without GM, and was on par with peanut-CTW/ZTW with or without GM and WSI (Table 1). As compared to sole peanut, peanut followed by ZTW and *Sesbania* increased system productivity by 75.0%. This might be owing to improvement in soil biochemical properties with conservation agriculture practices and legume green manuring. Among the green manure crops, *Sesbania* was found superior in terms of improved system productivity by 3.6% compared to green gram. Significantly

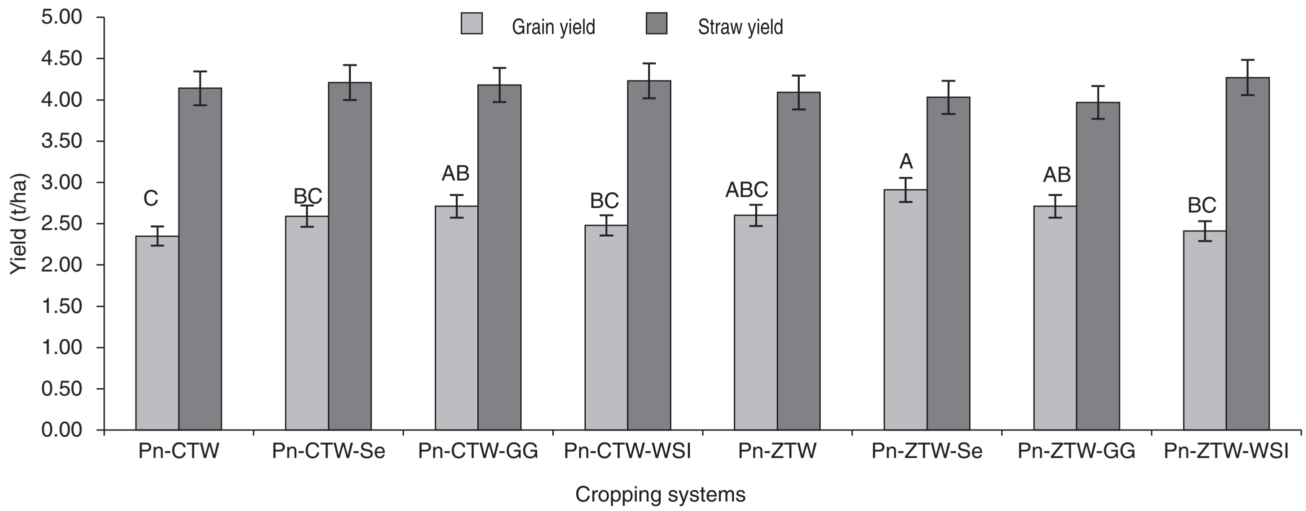

Fig 2 Wheat yield as influenced with conservation agriculture practices. Vertical bars represent the standard error (P=0.05). Means within the same column followed by superscripted different uppercase letter(s) are statistically different using Tukey's Honest Significant Difference Test at P<0.05.

higher system productivity of basmati rice-wheat cropping system with the incorporation of *Sesbania aculeata* green manure crop before transplanting of basmati rice was also reported by Pooniya and Shivay (2011) and was at par with incorporation of cowpea as green manure crop. Similarly, significantly higher system productivity (wheat equivalent yield) to the tune of 36% was recorded due to CA-based management under zero-till direct seeded rice-wheat-mungbean than conventional till rice-wheat system by Jat *et al*. (2019).

Sustainability indices: Peanut-ZTW-*Sesbania* cropping system recorded maximum sustainable yield index (0.46) owing to raising of *Sesbania* as green manure crop during summer, and adoption of zero tillage in wheat while minimum under sole peanut (0.15) irrespective of variation in weather (Table 1). It indicates that the minimum guaranteed yield obtained from this cropping system was 46%. Sustainable value index was also higher in peanut-ZTW-*Sesbania* (0.48) cropping system, while the minimum value recorded in sole peanut (0.10) (Table 1). Data also showed that peanut + pigeonpea intercrop with or without GM recorded higher sustainable yield (0.36–0.37) and income (0.35–0.40) than peanut with or without GM.

Thus, it could be concluded that peanut pod yield, wheat yield and system productivity were found significantly higher in peanut-CTW/ZTW and GM either with *Sesbania* or GG compared to sole peanut. GM with *Sesbania* in peanut+pigeonpea intercropping system recorded significantly higher pigeonpea seed yield over peanut+pigeonpea. Sustainability indices were also higher in peanut-ZTW-*Sesbania* than the other cropping systems. Thus, intensification of sole peanut through inclusion of either ZTW or CTW and GM with *Sesbania* or GG was found more productive and sustainable than sole peanut.

REFERENCES

Butter G S and Rana D S. 2014. Legumes as green manures. *Textbook of Plant Nutrient Management, part 18,* pp. 311–25. Prasad R, Kumar D, Rana D S, Shivay Y S and Tewatia R K (Eds). Indian Society of Agronomy, New Delhi.

Choudhary M, Rana K S, Bana R S, Ghasal P C, Choudhary G L, Jakhar P and Verma R K. 2017. Energy budgeting and carbon footprint of pearl millet – mustard cropping system under conventional and conservation agriculture in rainfed semi-arid agro-ecosystem. *Energy* **141**: 1052–8.

DES. 2019. *Agricultural Statistics at a Glance 2018*. Directorate of Economics and Statistics, Department of Agriculture Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi.

Jat S L, Shivay Y S and Parihar C M. 2011. Dual purpose summer legumes and zinc fertilization for improving productivity and zinc utilization in aromatic hybrid rice (*Oryza sativa*). *Indian Journal of Agronomy* **56**(4): 328–33.

Jat H S, Kumar P, Sutaliya J M, Kumar S, Choudhary M, Singh Y and Jat M L. 2019. Conservation agriculture based sustainable intensification of basmati rice-wheat system in North-West India. *Archives of Agronomy and Soil Science* **65** (10): 1370–86.

Jain N K, Jat R S, Meena H N and Chakraborty K. 2018. Productivity, nutrient and soil enzymes influenced with conservation agriculture practices in peanut. *Agronomy Journal* **110** (2): 1–8.

Moriri S, Owoeye L G and Mariga I K. 2010. Influence of component crop densities and planting patterns on maize production in dry land maize/cowpea intercropping systems. *African Journal of Agricultural Research* **5**(11): 1200–07.

Pooniya V and Shivay Y S. 2011. Effect of green manuring and zinc fertilization on productivity and nutrient uptake in basmati rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **56**(1): 28–34.

Sarma A. 2014. *Numerical Agronomy*, p 194. Kalyani Publishers, New Delhi, India.

Sharma A, Rathod P S and Basavaraj K. 2010. Agronomic management of pigeonpea (*Cajanus cajan*) based intercropping systems for improving productivity under rainfed conditions *Karnataka Journal of Agricultural Sciences* **23**(4) : 570–4.

Sharma S, Chander G and Verma T S. 2014. Nitrogen dynamics under long term *Lantana camara* (L.) residue and fertilizer application in a rice-wheat cropping system. *Journal of Plant Nutrition* **37**: 1804–16.

Singh A, Phogat V K, Dahiya R and Batra S D. 2014. Impact of long-term zero till wheat on soil physical properties and wheat productivity under rice-wheat cropping system. *Soil & Tillage Research* **140**: 98–105.

Singh A and Shivay Y S. 2013. Residual effect of summer green manure crops and Zn fertilization on quality and Zn concentration of durum wheat (*Triticum durum* Desf.) under a Basmati rice–durum wheat cropping system. *Biological Agriculture & Horticulture: An International Journal for Sustainable Production Systems* **29**(4): 271–87.

Singh R P, Das S K, Bhaskar Rao V M and Narayana Reddy M.1990. *Towards Sustainable Dryland Agricultural Practices*, pp.1-81. Central Research on Dryland Agriculture, CRIDA, Hyderabad, Telangana.

Srinivasarao Ch, Venkateswarlu B, Lal R, Singh A K, Kundu S, Vittal K P R, Balaguravaiah G, Babu M V S, Charya G R, Prasadbabu M B B and Reddy T Y. 2012. Soil carbon sequestration and agronomic productivity of an Alfisol for a groundnut-based system in a semiarid environment in southern India. *European Journal of Agronomy* **43**: 40–48.

Tojo Soler C M, Bado V B, Traore K, Bostick W M, Jones J W and Hoogenboom G. 2011. Soil organic carbon dynamics and crop yield for different crop rotations in a degraded ferruginous tropical soil in a semi-arid region: a simulation approach. *The Journal of Agricultural Science* (Cambridge) **149**(5): 579–93.

Yadav D, Shivay Y S, Singh Y V, Sharma V K and Bhatia A. 2018. Yield attributes, yields and nutrient uptake of *Basmati* rice (*Oryza sativa*) as influenced by *in-situ* and *ex-situ* green manuring crops and zinc fertilization. *Indian Journal of Agricultural Sciences* **88**(5): 671–8.