



## CROP SCIENCE

# Soybean herbage yield, nutritional value and profitability under integrated manures management

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**Abstract:** Organic manures are more preferred and environmentally friendly than chemical fertilizers for minimally contaminating soil, water and environmental resources, but the determination of right source of organic manures continues to remain an unexplored aspect. Considering the important issue, a multi-year field trial was carried out to determine the response of forage soybean to four sources of nutrients such as chemical fertilizers (IF), poultry litter (PL), bovine's farm yard slurry (BFYS) and sewage sludge (SS) and their seven binary combinations (PL+BFYS, PL+SS, PL+IF, BFYS+SS, BFYS+IF, SS+IF and PL+BFYS+SS). Supplementation of organic manures with mineral fertilizers remained superior to their sole application, particularly BFYS + IF was found significantly ( $p \leq 0.05$ ) superior for yielding the highest fresh biomass (23.9, 26.4 and 25.7 t ha<sup>-1</sup>) with improved nutritional quality. The same combination of integrated fertilizer management also recorded higher sustainability as per sustainable forage yield index along with the highest net income and the benefit-cost ratio. PL and SS applied in conjunction with IF performed better than sole or binary application of organic manures. Therefore, BFYS + IF may be recommended for adoption to produce comparable forage yield and nutritional quality of soybean along with reducing dependency on chemical fertilizers.

**Key words:** Chicken manure, Crude protein, Farm yard slurry, Plant nutrition, Sewage sludge.

## INTRODUCTION

Conventional crop production systems utilize inorganic fertilizers for plant nutrients which are criticized for contaminating water and environmental resources along with risk of disturbing marine and terrestrial ecosystems under changing climate (Strahinja et al. 2016, Iqbal 2018). In addition to ecological concerns, nutritionists are alarming of food and feed contamination in traditional farming systems (Melati et al. 2011, Ahmad et al. 2014). Moreover, regular increase in the prices of chemical fertilizers hinder their optimal use particularly

in developing countries, which necessitate exploring alternate sources of plant nutrients (Uchino et al. 2009, Iqbal et al. 2019a).

Organic manures have started to gain wide-scale support to be used as a source of plant nutrients owing to their potential to serve as supplementation to mineral fertilizers (Schmidt et al. 2001, Cavigelli et al. 2008, Kumar et al. 2013, Iqbal et al. 2014, Liu et al. 2021). Bedding materials of poultry sheds and slurry of bovine farm yards could be the potential sources of nutrients depending upon their chemical composition (Bandyopadhyay et al. 2010). In addition, sewage water containing suspended

sludge might also be used, but its performance for crop production needs to be examined before adoption as a source of plant nutrients (Avijit et al. 2016). Moreover, abundance of these organic materials owing to sufficient number of poultry sheds and dairy farms along with easy availability to farmers especially in Indo-Pak subcontinent also favor their utilization for crop production. Although organic manures (OM) are more preferred and environmentally friendly than chemical fertilizers (Cavigelli et al. 2008, Iqbal et al. 2019b) to minimize the contamination of soil, water and environmental resources, but farmers are not interested to use due to slow release and producing low yields as compared to chemical fertilizers (Rehman et al. 2017).

Dairy animals confront severe shortage of green forage during summer months in Pakistan (Iqbal et al. 2019b) and soybean (*Glycine max* (L.) Merr.) may be grown as an alternate forage due to containing double quantity of protein than cereals (Panneerselvam & Lourduraj 2000a, Iqbal et al. 2015). The agro-ecological and environmental conditions of Pakistan have been reported to be quite favorable for soybean production (Iqbal et al. 2018). Despite higher nutrition value, forage yield of soybean is less as compared to cereal forages (Bhattacharyya et al. 2008, Tunku et al. 2010, Iqbal et al. 2018). Nagar et al. (2016) found that application of farm yard manure ( $16 \text{ t ha}^{-1}$ ) gave the highest yield soybean, due to convenient decomposition and rapid release of nutrients compared to poultry manure ( $2.2 \text{ t ha}^{-1}$ ) and vermicompost ( $2.6 \text{ t ha}^{-1}$ ). In a complete contradiction, Yagoub et al. (2015) found that poultry manure ( $2.5 \text{ t ha}^{-1}$ ) resulted in improved yield of soybean, due to containing higher amount of nutrients than that of other organic manures. In addition, it was concluded that organic manures performed differently under varying agro-climatic conditions, since the site-specific evaluation of organic materials

was suggested (Andriamananjara et al. 2016, Blanchet et al. 2016, Hossain et al. 2017).

Up-till now, there is a serious lack of field investigations on organic manures utilization for forage soybean production in South Asian environment. However, it has been established that determination of the most productive organic sources and their judicious combination might lead to higher productivity and nutritional quality of forage soybean. Thus, it was hypothesized that combined application of different organic manures may produce comparable biomass of soybean as that of chemical fertilizers and organic manures applied in conjunction with chemical fertilizers (reduced doses) may outperform the solo application of inorganic fertilizers in terms of forage yield and quality. Therefore, this field investigation was executed with the prime objective to find out the most productive organic manure or their combination for boosting soybean yield, nutritional quality, sustainability and economic returns and ultimately reducing the dependence on chemical fertilizers.

## MATERIALS AND METHODS

### Experimental site

The field trial was conducted at the research farms of University of Agriculture Faisalabad, Pakistan; using different field locations during consecutive three years (2013, 2014 and 2015). The geographical coordinates of the experimental site are  $31^{\circ}26'5''\text{N}$  and  $73^{\circ}46''\text{E}$  with an altitude of 184 m above the sea level (Iqbal et al. 2019a). For pre-sowing physico-chemical analyses of soil as described by Jones (2001), soil samples were collected from middle and four corners of the experimental block up to the depth of 30 cm and were homogenized to make composite samples for subsequent analyses. The soil was sandy clay loam type with alkaline nature (pH

of 7.5–7.8) and severe deficiency of NPK along with the organic matter (Table I) The mean temperature during the crop growing season was 31–44°C, while the precipitation remained 140–157 mm.

### Experimental Details

Seeds of forage soybean (cv. Ajmeri having determinate growth) were collected from Fodder Research Institute, Sargodha, Pakistan. The experiment was comprised of three solo organic manures including poultry litter (PL) (3 t ha<sup>-1</sup>), bovine's farm yard slurry (BFYS) (6 t ha<sup>-1</sup>) and sewage sludge (SS) (7 t ha<sup>-1</sup>) and their seven binary combinations (PL+BFYS, PL+SS, PL+IF, BFYS+SS, BFYS+IF, SS+IF and PL+BFYS+SS). Treatments specifying co-application of organic and chemical manures contained 50% of their solo dose equivalents, while for combined application of three organic manures; their

dose was reduced by 75%. For treatment combinations, dose percentages were estimated on weight basis with respect to sole doses of chemical fertilizers and organic materials. For combined application, manures were mixed and then added to their respective plots. Sole chemical fertilizers (IF) (elemental NPK 80:40:20 kg ha<sup>-1</sup>) were applied in the form of urea, di-ammonium phosphate (DAP) and sulphate of potash (SOP). As the experimental soil was deficient in macro-nutrients (Table I) for being under exhaustive cereals for many years and thus considerably higher doses of N manures were applied to restore soil fertility. Every year, treatments were repeated in the same plots as that of previous years. The regular arrangement of the randomized complete block design was used to execute the field trial with four replicates. The net plot size was 6.6 × 18.0 m with 22 rows (30 cm spaced). Organic manures

**Table I. Experimental soil's analyses before the sowing of forage soybean for physical and chemical properties at Faisalabad, Pakistan.**

Soil characteristics	Values		
	2013	2014	2015
Physical analysis	2013	2014	2015
Sand (%)	56	55	57
Silt (%)	18.5	19.0	18.7
Clay (%)	25.5	26	27.3
Textural class	Sandy clay loam	Sandy clay loam	Sandy clay loam
Chemical analysis	2013	2014	2015
pH	7.8	7.7	7.5
EC (dSm <sup>-1</sup> )	1.63	1.58	1.67
OM (%)	0.65	0.68	0.72
N (mg kg <sup>-1</sup> )	325.7	333.1	349.0
P (mg kg <sup>-1</sup> )	6.9	6.7	7.1
K (mg kg <sup>-1</sup> )	191.6	186.0	179.9

were incorporated in the top soil (up to 30 cm depth) with the help of spade one week before sowing of forage soybean. In sole application of chemical fertilizers, whole of phosphorous and potassium were applied as basal dose while urea was applied with subsequent irrigations at 15 and 30 days after sowing.

### Composting of organic materials and their chemical analysis

Poultry litter and buffalo's farm yard slurry were obtained from poultry sheds and bovine farms situated at University of Agriculture Faisalabad, Pakistan. These organic materials were placed in earthen pits having the size of 4 m × 3 m × 1.5 m under anaerobic conditions. Urea (5% w/w) was also added to pits in order to increase the composting rate by increasing microbial population. These decomposing materials were placed as heaps into the pits and watered every week (Abdou et al. 2016). For chemical analysis, samples were collected from organic materials after 6 weeks and then before grinding, oven-drying was done at 65 °C for 48 hours. For storing grinded samples, zip lockable bags in triplicate were used. The pH of the organic manures was determined using pH meter. Parkin-Elmer analyzer was used to measure, while P,

K, Ca and Mg were estimated by following the methodologies as described by AOAC (2003) (Table II). Appropriate quantities of organic manures needed to reach the required level of nitrogen and phosphorous were quantified for sole application as well as combined application of two or more organic manures. Total amount of nutrients supplied through different manure sources is exhibited in Table III.

### Crop husbandry

To prepare a fine seed bed, 12 cm pre-sowing flood irrigation was applied, and then tractor drawn cultivator was used after the soil had attained appropriate soil moisture conditions. Planking with tractor drawn wooden plank followed each cultivation to obtain proper soil tilth for enhancing soil-seed interaction. Soybean (cv. Ajmeri using 100 kg ha<sup>-1</sup> seed rate) was sown in 30 cm spaced row using single row (cotton) drill. To prevent the onset of drought effects, three fortnightly irrigations were applied. At earlier growth stages of soybean, weed infestation was kept below threshold level using three manual hoeing at 14, 29 and 45 days after sowing. At 50% pod formation stage, soybean was harvested manually using hand sickle.

**Table II. Chemical composition of different organic manures and their combinations after composting.**

Manure source	Ph	N (g kg <sup>-1</sup> )	P (g kg <sup>-1</sup> )	K (g kg <sup>-1</sup> )	Ca (g kg <sup>-1</sup> )	Mg (g kg <sup>-1</sup> )
PL	7.4±1.14	29.3±1.10	11.7±0.22	7.3±1.25	8.6±0.67	3.2±0.39
BFYS	6.8±0.51	14.7±0.56	6.4±0.87	8.1±0.24	4.5±0.34	3.6±1.13
SS	7.0±1.35	12.1±0.43	5.2±0.34	5.9±0.91	3.8±1.20	3.0±0.67
PL+BFYM	7.2±0.94	20.4±0.94	12.0±0.10	8.4±1.27	7.2±0.11	3.3±0.28
PL+SS	7.3±0.36	18.0±0.37	8.8±0.94	6.3±0.39	7.0±0.67	3.0±0.37
BFYM+SS	7.1±0.24	13.8±0.14	9.2±0.64	6.4±0.33	6.1±1.64	3.2±0.37
PL+BFYM+SS	7.2±0.17	22.7±0.57	10.9±0.25	6.7±1.46	7.8±0.36	3.4±0.64

Poultry litter (PL), Bovine's farm yard slurry (BFYS), Sewage sludge (SS).

### Data collection

For data collection, ten soybean plants were randomly harvested from middle rows of experimental plots in each replication. Using tailor's measuring tap, plant height was recorded from base to the tip of the highest leaf. Vernier caliper was used to estimate stem girth from base, mid and top of the stem and then their means were calculated. Fresh weight of ten representative plants was measured by using electric balance in the field at the time of harvest. Green forage yield was recorded by harvesting all plants in an experimental unit and weighing them with a spring balance and then converted into tons per hectare. Ten plants were randomly harvested and chopped using an electrical fodder cutter and then mixed thoroughly before recording their fresh weight. Thereafter, 500 g sample was taken out from every lot and oven drying at 70°C was done until samples obtained a constant dry weight which was then used for estimating dry matter biomass. The nutritional quality traits of forage

soybean were also determined including protein content (Macro-Kjeldahl technique), crude fiber (acid digestion method), ether extractable fats (Soxhlet extraction method) and ash (muffle furnace technique) as outlined by Cherney & Cherney (2000) and AOAC (2003). Sustainable forage yield index (SFYI) was computed by following the procedure as outlined by Singh et al. (1996);

$$SFYI = (MFY - \sigma_{n-1}) / FYm \quad (1)$$

where, MFY and FYm are mean forage yield and maximum forage yield respectively, while  $\sigma_{n-1}$  represents standard deviation. Sustainable forage yield index helps to estimate the variation in biomass production under varying manure management systems with respect to highest forage yielding fertilizer regime.

### Economic analyses

In order to calculate gross and net income along with benefit to cost ratio, the recorded data of all three years were subjected to economic analysis

**Table III. The total amount of nutrients supplied through different sources and their combinations after composting.**

Manure source	N (kg ha <sup>-1</sup> )	P (kg ha <sup>-1</sup> )	K (kg ha <sup>-1</sup> )	Ca (kg ha <sup>-1</sup> )	Mg (kg ha <sup>-1</sup> )
PL	87.8±1.89	35.1±0.21	21.9±1.80	25.8±0.13	9.6±0.19
BFYS	88.2±0.61	38.4±1.29	48.6±0.31	27.0±0.64	21.5±1.14
SS	84.7±0.31	36.4±0.37	41.3±0.11	26.6±0.30	21.0±0.60
IF	80.0±0.84	40.0±0.67	20.0±0.61	-	-
PL+IF	83.9±0.12	37.5±0.80	30.9±0.30	12.9±0.19	4.8±0.31
BFYS+IF	84.1±0.26	39.2±0.19	44.3±0.40	13.5±0.20	10.7±0.45
SS+IF	82.3±0.30	38.2±0.37	40.5±0.67	13.0±0.64	7.0±0.92
PL+SS	85.1±0.94	36.7±0.94	31.5±1.27	25.9±0.94	11.8±0.60
PL+BFYM	88.0±0.84	35.6±0.67	35.2±0.31	26.4±0.11	15.5±1.13
BFYM+SS	86.4±0.67	37.4±0.61	44.7±1.20	26.5±1.34	17.7±0.54
PL+BFYM+SS	87.2±0.10	36.6±0.69	35.4±0.67	26.4±0.20	17.3±1.29

Poultry litter (PL), Bovine's farm yard slurry (BFYS), Sewage sludge (SS), Chemical fertilizers (IF).

by following the procedure as outlined by CIMMYT (1988). All fixed costs (land rent, labour, seed, cultivation, irrigations, hoeing, harvesting, transportation and local markup of 8% on investment) and variable costs (fertilization and associated labour) were added under the head of total expenditures (TE). The gross income during three years was calculated as:

$$GI = FY (\text{forage yield}) \times LMP (\text{local market price}) \quad (2)$$

This gross income was further used to calculate the net income (NI) in the following way;

$$NI = GI - TE \quad (3)$$

Gross income (GI) and total expenditures (TE) were used to compute the benefit to cost ratio (BCR) as described below;

$$BCR = GI / TE \quad (4)$$

Here GI and TE are same as in Eq. 1 and 2.

### Statistical analysis

Data were subjected to analysis of variance (ANOVA) technique using a statistical program "SAS" (Statistical Analysis System, version 9.5). Tuckey's honest significant difference (HSD) technique was further used to separate treatment's means at 0.05 level of significance (Iqbal et al. 2019a).

## RESULTS

### Plant height, stem girth, branches and leaves plant<sup>-1</sup>

After three years of observation, it was revealed that all fertilization regimes significantly influenced the yield attributes of soybean viz., plant height, stem girth, branches and leaves plant<sup>-1</sup>. Among them, plant height varied between 52.0 to 81.4 cm, while stem girth varied between

9.70 to 10.84 cm (Table IV). Among the fertilizers regimes, solo application of IF gave the tallest plant with the highest stem girth, branches as well as leaves plant<sup>-1</sup>, while sole application of PL produced the lowermost yield attributes. Although, BFYS supplemented with reduced doses of inorganic fertilizers also performed better, but it was not statistically at par to sole IF. However, performance of BFYS was found superior to other organic manures and their combinations.

### Fresh and dry weights plant<sup>-1</sup>, green herbage and dry biomass yield

Soybean responded differently to organic and chemical sources of nutrients, although application of IF applied solely were unmatched in terms of fresh and dry weight plant<sup>-1</sup>. Finally, it led to improved green forage yield (23.9, 26.4 and 25.7 t ha<sup>-1</sup> in 2013, 2014 and 2015), respectively and dry matter biomass (6.9, 7.9 and 7.3 t ha<sup>-1</sup> in 2013, 2014 and 2015 respectively). BFYS combination with IF followed by solo IF, while solo PL remained below-par to other organic manures as far as yield attributes and herbage yield of soybean were concerned (Table V).

### Nutritional quality of soybean

The co-application of BFYS+IF resulted in the highest crude protein and ether extractable fat with the lowest crude fiber content while it was statistically at par to sole application of IF. For total ash content, BFYS+IF remained superior to solo application of chemical fertilizers. PL recorded the lowest crude protein with highest crude fiber content when it was applied solely or in association with other organic manures and chemical fertilizers. Overall, the integrated application of organic materials and inorganic fertilizers remained superior to solo organic manures as well as organic manures applied in amalgamation with each other (Table VI).

**Table IV. Yield components of forage soybean as influenced by different mineral and organic fertilization regimes under irrigated conditions of Faisalabad, Pakistan.**

Treatments	Plant height (cm)			Stem girth (cm)			Number of branches plant <sup>-1</sup>			Number of leaves plant <sup>-1</sup>		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
PL	52.0d	54.3e	54.0e	9.70f	9.88g	9.77g	5.97e	5.87g	5.89f	17.0f	14.2f	15.8g
BFYS	60.9b	62.6d	63.4c	9.80de	10.20e	10.55c	6.30b	6.36d	6.16cd	18.1c	14.8d	16.9e
SS	60.0b	61.5d	58.4d	9.77e	10.05f	10.20f	6.19c	6.29e	5.90f	17.5d	15.1cd	16.2f
IF	68.7a	81.4a	75.6a	10.78a	10.84a	10.80a	6.66a	6.93a	6.51a	20.3a	16.5a	18.4a
PL+BFYS	56.1c	58.3de	55e	9.75e	10.11f	10.36e	6.17c	6.00f	6.13d	17.6d	14.3e	16.1f
PL+SS	55.0c	56.4e	55.6e	9.72ef	10.07f	10.19f	6.11d	6.26e	6.00e	17.3e	14.2e	16.3f
PL+IF	62.3b	65.1c	60.2c	9.96bc	10.41c	10.41d	6.21c	6.35d	6.21c	18.4bc	15.6c	17.4c
BFYS+SS	56.0c	60.0d	57.9d	9.91c	10.25de	10.38d	6.10d	6.26e	6.11d	18.0c	15.2cd	17.0d
BFYS+IF	66.1a	73.8b	68.9b	10.12b	10.66b	10.71b	6.59ab	6.71b	6.49a	18.9b	16.3ab	18.2ab
SS+IF	60.0b	62.9d	61c	10.0c	10.63b	10.58c	6.37b	6.55c	6.30b	18.6bc	16.0b	17.9b
PL+BFYS+SS	58.9bc	61.2d	60.4cd	9.88d	10.30d	10.55c	6.20c	6.39d	6.18cd	18.1c	15.4c	17.3c
F-test	**	**	**	*	**	**	*	*	**	*	**	*
CV (%)	19.21	11.14	18.00	21.29	18.89	16.33	10.29	14.51	13.63	15.19	20.18	17.84

Values followed by different letters within columns differ significantly at the significance level of 0.05. Poultry litter (PL), Bovine’s farm yard slurry (BFYS), Sewage sludge (SS), Inorganic fertilizers (IF).

**Sustainable forage yield index (SFYI) and economic benefits**

Sustainable forage yield index (SFYI) varied from 0.34–1.03; although SFYI was decreased with the sole application of organic manures, however it was improved with the integrated application of organic manures in combination with reduced doses of chemical fertilizers. The highest SFYI (0.99, 0.97 and 1.03 in 2013, 2014 and 2015 respectively) was recorded by co-application of BFYS and IF which was closely followed by sole application of IF (Fig. 1). SS as well as PL applied solely or in combination with other organic manures recorded the lowest SFYI.

As far as economic turnouts were concerned, sole application IF documented considerably higher gross income and net income, closely followed by integrated use of IF and BFYS, while integrated use of organic manures in combination with reduced doses of chemical fertilizer proved to be superior to sole application of IF in terms of the benefit-cost ratio. No other organic manure or combination of organic manures was found to be at par to

BFYS+IF, especially PL alone gave the lowest gross and net incomes along with the benefit-cost ratio (Table VII).

**DISCUSSION**

Comparatively low productivity under organic manures continues to remain one of the biggest hurdles in their wide-scale adaptation (Aziz et al. 2011, Ruibo et al. 2015). This situation demands for urgent strives for testing different organic materials or their combinations to produce comparable yields as that of chemical fertilizers. In this study, sole application of chemical fertilizers (IF) which provide readily available plant nutrients in comparison to organic manures (Behera et al. 2007, Thelen et al. 2010) remained unmatched by recording the maximum yield attributes and herbage yield (Tables IV and V). However, co-application of organic manures with reduced doses chemical fertilizers performed better than the sole application of organic manures or combinations

**Table V. Yield attributes, herbage yield and dry matter biomass of soybean as influenced by different mineral and organic fertilization regimes under irrigated conditions of Faisalabad, Pakistan.**

Treatments	Fresh weight plant <sup>-1</sup> (g)			Dry weight plant <sup>-1</sup> (g)			Herbage yield (t ha <sup>-1</sup> )			Dry biomass yield (t ha <sup>-1</sup> )		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
PL	119.8e	125.9e	121.9f	41.9e	42.5e	40.3f	21.8e	21.0f	20.6e	5.0e	5.1e	5.3e
BFYS	135.0c	144.0c	128.9de	45.7bc	51.1bc	44.4de	23.0bc	24.9bc	23.1bc	5.8cd	6.7bc	6.4bc
SS	121.7e	133.6d	125.6e	41.1e	42.8e	42.0e	21.3cd	22.3d	21.4d	5.4d	5.3de	5.5de
IF	153.3a	166.4a	159.7a	47.9a	54.1a	52.1a	25.7a	28.8a	26.4a	6.9a	7.9a	7.3a
PL+BFYS	129.4d	135.9d	146.0cd	42.8d	44.6de	45.1d	22.1cd	22.0de	22.1cd	6.1c	5.7d	6.4bc
PL+SS	127.1d	127.9e	130.5e	43.9cd	44.0de	47.0cd	21.6d	21.4e	21.5d	5.2de	5.4de	5.8d
PL+IF	142.9b	147.0c	148.9c	45.8b	45.9cd	47.2cd	23.1bc	24.0c	23.6bc	5.9cd	6.2cd	6.4bc
BFYS+SS	137.5c	145.9c	146.2cd	44.1c	45.0d	45.8d	22.4c	21.0ef	22.9c	5.5d	5.8d	6.2c
BFYS+IF	151.9a	156.9b	158.4a	47.3a	52.7b	50.4b	23.9b	26.4b	25.7ab	6.6ab	7.3b	6.7b
SS+IF	144.8b	150.2bc	151.5b	46.0ab	49.9c	48.0c	23.0bc	23.4cd	24.0b	6.1c	6.5c	6.5bc
PL+BFYS+SS	141.0b	143.8c	141.0d	44.2c	46.5cd	46.1d	22.0cd	22.7d	23.3bc	6.0cd	6.4c	6.0cd
F-test	*	**	**	*	*	**	**	**	**	*	**	**
CV (%)	13.50	20.93	15.27	10.54	18.21	14.14	13.84	17.52	11.15	14.28	23.29	14.99

Values followed by different letters within columns differ significantly at the significance level of 0.05.

Poultry litter (PL), Buffalos farm yard slurry (BFYS), Sewage and sludge (SS), Inorganic fertilizers (IF).

of organic manures in term of yield attributes and forage biomass. Especially, integrated use of bovine's farm yards slurry (BFYS) and IF remained superior for improving the agronomic traits as well as herbage yield. This difference in performance was likely to be associated with comparatively rapid release of nitrogen from IF which supported better vegetative growth of soybean as reported by Mandal et al. (2009) and Yang et al. (2015). Although, poultry manure contained much higher nitrogen along with calcium and magnesium than other organic manures (Table II), but it has been previously reported to provide nutrients slowly (Moreira et al. 2015), which negatively affected the vegetative growth of soybean as demonstrated by lower plant height, stem girth and fresh weight per plant (Tables IV and V). In addition, the shade of crop plants slowed down the decomposition of chicken manure unlike to livestock's slurry (Panneerselvam & Lourduraj 2000b). In this trial, poultry litter (PL) did not perform at par to BFYS which suggests that bovine's farm yard slurry has the potential to replace the traditional nutrient management systems.

However, most of the agricultural lands are severely deficient in nitrogen and thus abandoning the use of inorganic fertilizers cannot be recommended as organic manures may not obtain comparable yields (Padovan et al. 2002, Yang et al. 2015). But as in this experiment, binary application of bovine's farm yard slurry and reduced doses of chemical fertilizers yielded the comparable forage biomass which helped in reducing the dependence on chemical fertilizers. This approach could also cause the buildup of soil organic matter in the long run, improvement of physico-chemical properties and water holding capacity of soil. (Nakamura et al. 2007, Khaliq & Abbasi 2015). In contrary, some of the earlier studies (Ramesh et al. 2009, Islam et al. 2010, Ismaeil et al. 2012) have reported significantly less forage yield (8–17 t ha<sup>-1</sup>) by using these organic materials (buffalos and cows farm yard slurry, chicken manure, composted green manure, sewage and sludge etc.) which indicated that quality of organic manures in such investigations is critical as lower quality might lead to significant reduction in biomass production.



**Table VI. Nutritional quality of forage soybean as influenced by different mineral and organic fertilization regimes under irrigated conditions of Faisalabad, Pakistan.**

Treatments	Crude protein (%)			Crude fiber (%)			Ether extractable fat (%)			Ash (%)		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
PL	18.1d	18.5e	19.0e	26.2a	25.4a	25.9a	1.66f	1.70e	1.74e	9.3e	9.8e	9.9f
BFYS	18.7bc	20.4c	19.2de	24.2e	24.0e	24.7d	1.78c	1.81cd	1.83cd	10.0cd	10.2d	9.97e
SS	18.3cd	19.3d	19.4d	25.9b	25.1b	25.5b	1.74d	1.77d	1.83c	9.5de	10.1cd	10.0d
IF	20.1a	21.4b	21.0a	23.6f	23.4f	23.7g	1.91a	1.97a	1.94a	11.0a	11.3a	11.1a
PL+BFYS	18.4cd	20.7bc	19.2de	25.6bc	25.0b	25.3bc	1.70e	1.72e	1.80d	9.8d	10.3d	10.3c
PL+SS	18.1d	19.8cd	19.5d	25.2c	24.8c	25.0c	1.67f	1.71e	1.82c	9.6de	10.2cd	10.4c
PL+IF	19.0b	20.9bc	20.2c	25.5bc	24.7c	24.2e	1.80c	1.83c	1.86bc	10.7b	11.0b	10.8b
BFYS+SS	18.8bc	20.5c	19.8cd	24.8d	24.6cd	24.8d	1.79c	1.80d	1.86bc	10.2c	10.4c	10.5bc
BFYS+IF	19.9a	21.9a	20.9a	23.9ef	23.0g	24.0f	1.84b	1.91b	1.89b	10.9a	11.2a	11.0a
SS+IF	18.9bc	20.4c	20.4b	24.6de	24.2d	24.3e	1.82bc	1.86c	1.87bc	10.5bc	10.9bc	10.6bc
PL+BFYS+SS	18.5c	20.8bc	20.1c	24.6de	24.3d	24.4e	1.79c	1.79d	1.85bc	10.3c	10.6c	10.4c
F-test	*	**	**	**	*	**	*	*	**	*	**	**
CV (%)	10.97	17.24	14.28	15.00	12.67	21.28	23.07	18.57	14.36	16.21	14.14	17.41

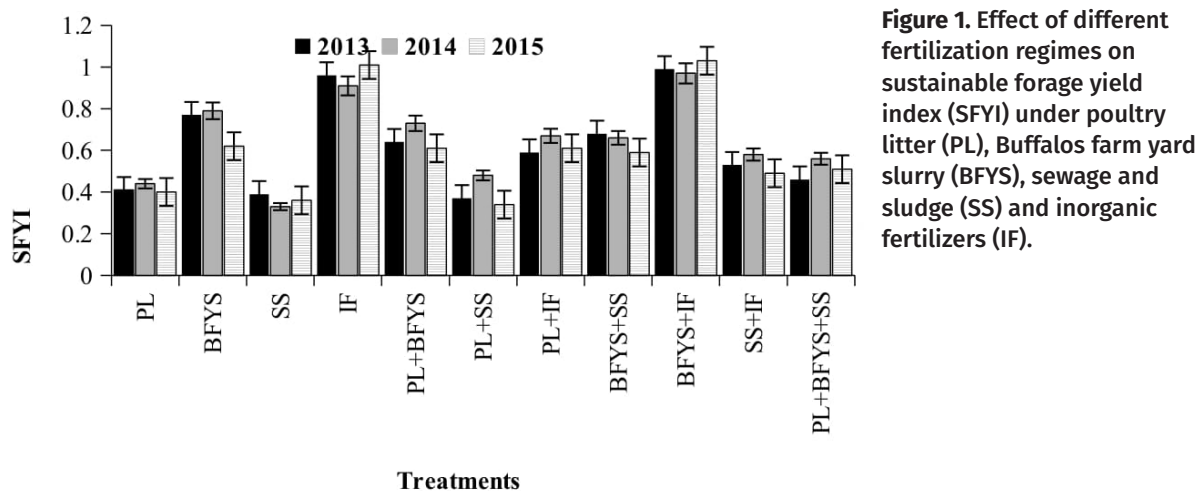
Values followed by different letters within columns differ significantly at the significance level of 0.05. Poultry litter (PL), Buffalos farm yard slurry (BFYS), Sewage and sludge (SS), Inorganic fertilizers (IF).

This multi-year field trial showed that BFYS applied in conjunction with IF improved the nutritional value of soybean forage by recording the highest crude protein and the lowest crude fiber of forage soybean (Table VI). These results showed that the combined application of organic and inorganic manures support better quality forage by supplying N from chemical fertilizers to fulfill immediate needs while organic manures keep on supplying N as result of slow and steady decomposition over a longer period of time (Bandyopadhyay et al. 2010). There existed a positive synergy between N availability and crude protein content as plant immediately convert readily available N into protein (Zhang et al. 2015). Furthermore, sufficient nitrogen supply was found to reduce the crude fiber content because it has an inverse relationship to nitrogen availability (Panneerselvam & Lourduraj 2000a, Abusuwar & El-Zalal 2010, Aziz et al. 2011, Mohammadi 2015).

Fats and ash are equally important indicators of forage quality for maintaining numerous metabolic processes of ruminants. Significantly higher fats and ash contents recorded by the

combined application of BFYS+IF indicated that reducing the dose inorganic fertilizers had no drastic impact on forage nutritional quality. These findings are in contradiction to Mariotti et al. (2001) who recorded a non-significant effect of organic manures on fat and ash content. However, the findings of Arif et al. (2016) and Memon et al. (2012) corroborated to these results as integrated application of cattle slurry (5 t ha<sup>-1</sup>) urea (30 kg ha<sup>-1</sup>) resulted in improved nutritional quality. It was also concluded that cattle slurry provided macro (NPK) and micro nutrients (Zn, Ca, Mg etc.) which triggered vegetative growth and also improved the nutritional quality.

Sustainable forage yield index (SFYI) depicts the level of sustainability of any treatment in forage production over the years. Significantly higher SFYI recorded by combined application of organic manures and chemical fertilizers (Fig. 1) suggested that their co-application is more sustainable compared to their sole application. Unkovich et al. (2010) also reported that synchronized application of organic materials with chemical fertilizers remained more sustainable than their sole application. It was



**Figure 1.** Effect of different fertilization regimes on sustainable forage yield index (SFYI) under poultry litter (PL), Buffalos farm yard slurry (BFYS), sewage and sludge (SS) and inorganic fertilizers (IF).

**Table VII.** Economic analyses of forage soybean as influenced by different chemical and organic fertilization regimes under irrigated conditions of Faisalabad, Pakistan.

Treatments	TE (US\$ ha <sup>-1</sup> )	GI (US\$ ha <sup>-1</sup> )	NI (US\$ ha <sup>-1</sup> )	BCR
PL	498±0.11	840±0.52	342±0.90	1.68±0.42
BFYS	473±0.37	956±0.33	483±0.24	2.02±0.81
SS	460±0.95	892±0.81	432±0.17	1.93±0.33
IF	607±0.42	1217±0.67	610±0.36	2.00±0.16
PL+BFYS	479±0.39	880±0.91	401±0.42	1.83±0.42
PL+SS	470±0.48	864±0.22	394±0.78	1.83±0.27
PL+IF	526±0.62	960±0.53	434±0.94	1.82±0.91
BFYS+SS	448±0.11	841±0.49	393±0.27	1.87±0.77
BFYS+IF	521±0.57	1099±0.84	578±0.28	2.10±0.64
SS+IF	515±0.97	936±0.21	421±0.13	1.81±0.42
PL+BFYS+SS	480±0.24	908±0.49	428±0.78	1.89±0.13

Poultry litter (PL), Buffalos farm yard slurry (BFYS), Sewage and sludge (SS), Inorganic fertilizers (IF). Total expenditures (TE), Gross

also concluded that synchronized application of organic and chemical manures did not carry risk to sharply reduce herbage yields over the years as indicated by sustainable yield index and have the potential to produce forage as per varietal potential. Similarly in this research, considerably higher profitability was recorded by integrated use of organic manures and chemical fertilizers (Table VII) which depicted that organic manures have the potential to reduce the doses

of expensive fertilizers and enhance economic returns by reducing the cost of production. Khan et al. (2013) also reported that organic manures applied in amalgamation to chemical fertilizers was more viable and profitable than solo applied organic manures especially in N-deficient soils. Thus, it could be inferred that organic manures especially bovine’s farm yard slurry applied in association with reduced doses of chemical fertilizers has the potential to restore and

preserve soil fertility, generate higher revenues along with being an environmental friendly approach. However, future strives need to focus on improving the quality of organic manures with better nutrient composition for their global acceptance as an effective alternate of chemical fertilizers in boosting crops productivity and ensuring the food security rapidly increasing population.

## CONCLUSION

It was hypothesized that different combinations of organic manures could perform at par to solo application of mineral fertilizers but the result indicated that all combinations of organic manures remained inferior to chemical fertilizers. However, integrated fertilization of bovine's farm yard slurry and chemical fertilizers performed better than other combinations as far as biomass production, nutritional quality and economic returns of soybean were concerned. The same fertilization regimes imparted the maximum sustainability to forage soybean production as per sustainability yield index. However, there is dire need to evaluate organic manures of different origins to obtain comparable forage yield and nutritional quality of forage soybean as that of chemical fertilizers.

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