International Scholars Journals

African Journal of Crop Science ISSN 2375-1231 Vol. 3 (5), pp. 165-175, July, 2015. Available online at www.internationalscholarsjournals.org

Full Length Research Paper

Effect of green manuring jantar (*Sesbania Acculata.* l.) on the growth and yield of crops grown in wheat-based cropping systems

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Accepted 28 July, 2015

A proposed field study of wheat-based cropping systems was conducted at Faisalabad (Post-Graduate Research Station). We used 7 treatments and Jantar as a green manuring crop to increase the fertility status of soil; after the vegetative phases of wheat, rice, sorghum, and mungbean, the agronomic parameters of these crops were recorded. hopefully all increased with jantar treatment when compared with controls. The benefit: cost ratio and physicochemical characteristics of the soil before and after the crop harvest were also calculated.

Key words: Benefit cost ratio, fertility status of soil, Jantar, physicochemical characteristics of the soil, wheat-based cropping systems.

INTRODUCTION

The fertility of soils in Pakistan is decreasing due to intensive cultivation of crops and the use of nutritional elements in low quantities. Deficiencies in different crop growth elements have been reported by many groups (Soetan et al. 2010.) Adding inorganic fertilizers is a good way of correcting the deficiency of nutritional elements, but they not only add to the cost of production but often are not available to meet the demands of farmers. Although the fertilizers are very effective in increasing yield, they may deteriorate the soil structure and pollute the groundwater. In addition, chemical fertilizers are expensive due to the energy crisis and are unavailable to many farmers, particularly in developing countries. In this situation, green manure can serve as a cheaper source of plant nutrition and has become popular with farmers. Green manuring is the process of growing leguminous crops and ploughing the same in soil. On decomposition, it results in increased soil fertility. At the same time, improving the organic matter content of soil also improves its water-holding capacity, aeration, colloidal complex, and hence its ability to retain nutrients.

The soils of Pakistan are generally low in organic matter due to higher decomposition rates and low addition of organic residues in the soil, because green manuring is practiced at a very low scale. Biological nitrogen fixation by some legumes and their incorporation into the soil as green manure can substitute for artificial fertilizers, which will not only reduce the cost of production but also maintain and improve the fertility of the soil. Jantar is a very suitable crop for this purpose and can be adjusted in the present cropping system (Aulakh et al., 2001). Soil productivity can be enhanced through the utilization of organic matter and green manuring (Mohammadi et al. 2011).

In Pakistan wheat-cotton, wheat-rice, wheat-pulses, and wheat-summer fodders are the major cropping systems that are adopted by the farming community. In the districts of Sialkot, Gujranwala, Sheikhupura, Lahore, Kasur, and Gujrat, the most prevalent cropping system is rice-wheat. In these districts, about 73% of wheat is rotated with rice, followed by wheat-cotton, wheat-summer pulses, and wheat-summer fodders. These cropping systems are exhaustive and deplete soil fertility by deteriorating its physical, chemical, and biological properties. Therefore, there is a need to replenish the soil by adding a green manure crop in these cropping systems and adding crop residues in the soil. Thus, this study examined the effects of jantar as a green manure crop in wheat-based cropping systems.

MATERIALS AND METHODS

The proposed study was conducted at the Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad, on sandy clay loam soil. Wheat crop of rabi was harvested with a combine harvester. Jantar crop was sown as the green manure crop, as the relay crop in treatments T3, T5, and T7, and as the sequence crop in T2, T4, and T6. The various kharif crops were planted after rotavating the Jantar crop according to the treatment schedule during the kharif season. Yield and yield parameters of these crops were recorded. In the following rabi season, wheat was planted in all cropping systems. The effects of green manuring and the kharif crops on wheat planted during the following rabi season were studied.
Rice, mungbean, and sorghum were sown as a sequential pattern after wheat. The experiment was set up in randomized, complete block design with three replications. The net plot size was 12 m. A physicochemical analysis of the soil before green manure crop and after completion of the crop rotation was carried out.
The experiment comprised the following treatments/crop rotations:

Tl	=	Wheat-rice-wheat
T2	=	Wheat-jantar-rice-wheat
T3	=	Wheat/jantar-rice-wheat
T4	=	Wheat-jantar-sorghum-wheat
T5	=	Wheat/jantar-sorghum-wheat
T6	=	Wheat-jantar-mungbean-wheat
T7	=	Wheat/jantar-mungbean-wheat

Wheat/Jantar refers to the relay cropping of jantar in wheat, while wheat-jantar indicates the sowing of janter in sequence after the wheat harvest. Crops in the proposed cropping sequence above were sown per their recommended sowing times. All agronomic practices for raising these crops were applied uniformly. Crops were harvested when they attained their physiological maturity. However, jantar was ploughed up at the blooming stage as green manure crop. The following observations on the growth and yield parameters of the crops were taken made per standard procedures:

PROCEDURES FOR TAKING OBSERVATIONS

The procedures used for recording observations on different parameters of the component crop were as follows.

WHEAT

1. Plant height at maturity (cm)

Ten tillers were selected at random from each plot at harvest. Their heights were measured, recorded, and then averaged.

i. Number of plants per m^2
An area of one square meter was marked at random at three different locations in each plot and, the number of plants was counted.

ii. Number of tillers per m^2
All the tillers, whether bearing spikes or not, in a unit area of one square meter were counted and recorded from every plot randomly at harvest.

iii. Number of productive tillers per m^2
The number of spike-bearing tillers in a unit area of one **m^2** was counted from three sites randomly and then averaged.

iv. Number of grains per spike
Ten spikes from each plot were taken randomly. They were threshed by hand, and their grains were counted and averaged to calculate grains per spike.

v. 1000-grain weight (g)
1000 grains were taken at random from a lot of each plot by counting and weighing.

vi. Grain yield (t ha^{-1})
Grain yield was recorded on a net plot basis in kg and then calculated in tones per hectare.

vii. Straw yield (t ha^{-1})
Straw yield was calculated by subtracting the grain yield from biological yield.

viii. Harvest index (%)
Harvest index (H.I) for each treatment was computed using the following formula:

$$\text{H.I.} = \frac{\text{Economic Yield} \times 100}{\text{Biological yield}}$$

RICE

i. Plant height at maturity (cm).
Ten plants from each plot were selected randomly. The height of each plant was measured with a meter rod, and the average was calculated.

ii. Number of plants per m^2.
The number of plants from a unit area of one square meter of each plot was counted after complete germination.

iii. Number of tillers per plants.
The number of tillers per plant was counted by selecting 10 plants randomly from each plot.

iv. Number of panicle-bearing tillers per m^2.
Of the total number of tillers per unit area in each plot, the panicle-bearing tillers were sorted out, counted, and then calculated on a per-m^{-2} basis.

v. Number of spikelets per panicle.
Ten panicles were randomly selected from different plants, and the number of spikelets was calculated.

vi. 1000-kernal weight (g).
Three samples of 1000 grains from each paddy lot of each plot were taken and weighed, and the average 1000-grain weight was calculated.

vii. Paddy yield (t ha^{-1})
Paddy yield was recorded in kg per plot and then converted into t ha^{-1}.

viii. Straw yield (t ha^{-1})

Straw yield was recorded in kg per plot and then converted into t ha^{-1}.

ix. Harvest index (%)

Harvest index was calculated using the following formula:

$$H.I. = \frac{\text{Paddy yield}}{\text{Biological yield}} \times 100$$

MUNGBEAN

i. Number of plants m^{-2}.

It represents the number of growing plants per square meter at harvest. It was calculated by counting the number of plants from two 1-meter rows from each subplot at three randomly selected places and converting it to the number of plants m^{-2}.

ii. Number of pods per plants.

The total number of pods of 20 randomly selected plants from each subplot was counted, and their average was calculated.

iii. Number of seeds per pod.

Total number of pods removed from 20 randomly selected plants was threshed, and the grains were counted and averaged.

iv. 1000-seed weight (g)

Three samples of 1000 seeds were taken from each subplot, their weight was recorded separately with and electrical balance, and the average values were computed.

v. Seed yield (t ha^{-1})

After harvesting and sun-drying, threshing was done manually. Sun-dried bundles from each experimental plot were mechanically threshed to determine grain yield and converted into t ha^{-1}.

vi. Straw yield (t ha^{-1})

Straw yield was recorded in kg per plot and converted into t ha^{-1}.

vii. Harvest index (%)

Harvest index (H.I.) for each plot was computed by the following formula.

$$H.I. = \frac{\text{Economic Yield}}{\text{Biological yield}} \times 100$$

SORGHUM

i. Number of plants m^{-2}.

The number of plants was counted in one square meter at three randomly selected places in each plot, and the averages were calculated.

ii. Plant height at maturity (cm).

The plants were randomly selected from each plot; their height was measured from the base to the tip of the highest leaf with a measuring tap, and their averages were calculated.

iii. Fodder yield (t ha^{-1})

All pots of each replication were harvested, weighed separately to obtain the yield in kg $plot^{-1}$, and converted to tones ha^{-1}.

Economic Analysis:

The cost of production for each cropping system was calculated to determine the net returns.

1. Net income (Rs. Ha^{-1})

Net income was calculated as

Net income = Gross income – Cost of production

2. Benefit cost ratio

Benefit cost ratio was calculated as:

$$BCR = \frac{\text{Net income}}{\text{Total Cost}}$$

Physicochemical analysis of soil

The physical and chemical properties of soil were determined per standard methods (Nelson and Sommers, 1982).

Macro- and micronutrients in soil

Soil samples, 5 g each, were collected from the experimental pots at a uniform depth of 5 cm, suspended in 50 ml of distilled water, stirred continuously for 20 min, and filtered. The filtrate was used for the analysis.

Electrical conductivity

Five grams of soil was mixed with 50 ml distilled water and stirred for 1 h. The suspension was left overnight to allow the soil to settle to the bottom. The electrical conductivity of the supernatant was determined using an Ec meter.

Soil pH

Soil samples (25 g each) were placed in 100 ml beakers, each filled with 25 ml of distilled water, and stirred for 10 min before recording the pH (Recommended soil chemical test procedure, 1988).

Moisture content

Soil samples (20 g each) were taken from a uniform depth of 5 cm. The fresh weight of the samples was recorded. Dry weight was determined after drying the soil in an oven for 72 h at 70°C to a constant weight, and the moisture percentage was calculated.

Fresh weight and dry weight

The fresh weight of the seedlings was recorded upon harvest. Dry weight was recorded after drying the seedlings in an oven at 70°C for 24 h.

Determination of nitrogen, phosphorus, potassium, calcium, magnesium, iron, and manganese

Nitrate-nitrogen was determined per Soltanpour and Schwab

(1977); K, Mg, Mn, and Ca were extracted from the soil sample, as described by Mehlich (1953 and 1984); and concentrations of Fe, Mg, Mn, and Zn were determined using an atomic absorption spectrophotometer (Shimadzu, AA- 670). Solutions for the spectrophotometry were prepared per Whitney (1988).

Statistical analysis

The data was analyzed statistically using Fisher's analysis of variance technique, and the treatment means were compared using the least significant difference (LSD) test at a 0.05 probability level (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Various cropping systems were studied at PARS. Wheat crop of rabi was the harvester. Jantar crop was sown as the green manure crop; as the relay crop in treatments T3, T5, and T7; and as the sequence crop in T2, T4, and T6.The various kharif crops were planted after rotavating the jantar crop according to the treatment schedule during the kharif season. The yield and yield parameters of these crops were recorded. In the following rabi season, wheat was planted in all cropping systems. The effects of the green manuring and the kharif crops on wheat that was planted during the following rabi season were studied.
The data on yield and yield parameters of this wheat crop were recorded and are discussed below.

1). Plant height at maturity (cm)

The data regarding plant height are presented in Table 1. The plant height of wheat was affected significantly by various planting systems. A maximum plant height of 85 cm was recorded in the wheat/janatar–rice wheat (T3) cropping system. All cropping systems except, T1 (Wheat-rice wheat) and T5 (wheat/janatar-sorghum-wheat), yielded similar plant heights. The lowest plant height (80.5 cm) was on par with the T5 (wheat/jantar-sorghum-wheat) cropping system.
The higher plant height in the wheat/jantar-rice-wheat (T3) system was attributed to the favorable effect of green manuring and the beneficial effect of the previous crop on soil fertility. The higher plant height in this treatment might have been at the expense of nitrogen that could have been fixed by the jantar crop.
These results are consistent with those of Khan *et al.* (1968) and Saleem (1993). They reported that green manuring of soil increased the plant height of following wheat.

2). Number of plants per m -2

The data regarding the number of plants per m^{-2} are presented in Table 2. The number of plants m^{-2} was not affected significantly by the various cropping systems. The highest number of plants **m^{-2}** was recorded in the wheat-rice-wheat (T1) cropping system. The lowest number of plants m^{-2} was recorded in the wheat/jantar-rice-wheat (T3) cropping system. Thus, the previous crop did not have favorable or adverse effects on seed germination, and germination depends entirely upon the seed condition and health. These results contrast those of Muzzaffar (1994), who reported that green manuring increases the number of plants m^{-2}.

3). Number of tillers m^{-2}

The data regarding the number of tiller m-2 are shown in Table 3. The number of tillers m-2 was affected significantly by the various planting systems. The wheat-jantar-mungbean-wheat system generated the highest number of tillers m-2 (364.67), followed by wheat-jantar-rice-wheat (360.33), wheat-rice-wheat (357.67), T1 (357.67), T5 (355.67), and T7 (357.00). The lowest number of tillers (352.00) was recorded in the wheat-jantar-sorghum-wheat cropping system, because in that season, the sorghum was comparatively exhaustive, which might have depleted the soil fertility; thus, the following wheat crop suffered from a lack of nutrition, resulting in a lower number of tillers. These results are consistent with Khan *et al.* (1968), who reported that green manuring increases the number of tillers m^{-2}.

4. Number Of Productive Tillers m^{-2} of Wheat

The number of productive tillers m-2 is a key component of the yield of wheat. The data regarding the number of productive tillers m-2 of wheat are shown in Table 4 and Figure 6.
The number of productive tillers m-2 was affected significantly. The wheat/jantar-sorghum-wheat system effected an increase in the number of productive tillers m-2 (252.67), followed by the wheat-jantar-mungbean-wheat (T6) system (236.67). The wheat-jantar-rice-wheat (T2) and wheat-jantar-sorghum-wheat (T4) systems were statistically equal. The lowest number of productive tillers was in the wheat-rice-wheat system, might have been due to the depletion of soil fertility, subjecting the following wheat crop to nutrient deficiency. These results are consistent with Muzaffar (1994), who reported that green manuring increases the number of productive tillers m-2.

5. Number of grains spike^{-1}

Grains per spike is an important yield component in cereals and is influenced by wheat-based cropping systems. The data Table 5 and Figure 7 demonstrate that the number of grains per spike of wheat crop was not affected significantly in various cropping systems. The number of grains spike^{-1} varied from 41.75 to 45.67 in various plots. These results contrast those of Khan et al.

Table 1. Plant height of wheat at maturity (cm).

Individual comparison of treatment		Means
	Treatments	Means
T1	wheat-rice-wheat	80.50 c
T2	wheat-jantar-rice-wheat	82.33 abc
T3	wheat/jantar-rice-wheat	85.00 a
T4	wheat-jantar-sorghum-wheat	83.67 ab
T5	wheat/jantar-sorghum-wheat	81.00 bc
T6	wheat-jantar-mungbean-wheat	84.67 a
T7	wheat/jantar-mungbean-wheat	83.00 abc
	LSD	2.50

Any two means that do not share letters differ significantly at P<0.05.

Table 2. Number of plants m^{-2} of wheat per cropping system.

Individual comparison of treatment		Means
	Treatments	**Means**
T1	wheat-rice-wheat	229.33
T2	wheat-jantar-rice-wheat	221.33
T3	wheat/jantar-rice-wheat	210.33
T4	wheat-jantar-sorghum-wheat	214.00
T5	wheat/jantar-sorghum-wheat	221.00
T6	wheat-jantar-mungbean-wheat	219.67
T7	wheat/jantar-mungbean-wheat	219.00

Table 3. Number of tillers m^{-2} of wheat per cropping system.

Individual comparison of treatment		Means
	Treatments	Means
T1	wheat-rice-wheat	357.67 bc
T2	wheat-jantar-rice-wheat	360.33 b
T3	wheat/jantar-rice-wheat	354.00 de
T4	wheat-jantar-sorghum-wheat	352.00 e
T5	wheat/jantar-sorghum-wheat	355.67 cd
T6	wheat-jantar-mungbean-wheat	364.67 a
T7	wheat/jantar-mungbean-wheat	357.00 cd
	LSD	2.91

Any two means that do not share letters differ significantly at P<0.05.

Table 4. Number of tillers m-2 of wheat per cropping system

Individual comparison of treatment		Means
	Treatments	Means
T1	wheat-rice-wheat	190.67 d
T2	wheat-jantar-rice-wheat	223.00 bc
T3	wheat/jantar-rice-wheat	209.67 cd
T4	wheat-jantar-sorghum-wheat	222.00 bc
T5	wheat/jantar-sorghum-wheat	252.67 a
T6	wheat-jantar-mungbean-wheat	236.67 ab
T7	wheat/jantar-mungbean-wheat	208.67 cd
	LSD	21.26

Any two means that do not share letters differ significantly at P<0.05

Table 5. Number of grains spike-1 of wheat per cropping system.

Individual comparison of treatment		Means
	Treatments	Means
T1	wheat-rice-wheat	44.91
T2	wheat-jantar-rice-wheat	43.44
T3	wheat/jantar-rice-wheat	41.75
T4	wheat-jantar-sorghum-wheat	45.75
T5	wheat/jantar-sorghum-wheat	45.33
T6	wheat-jantar-mungbean-wheat	45.67
T7	wheat/jantar-mungbean-wheat	45.33

(1968) and Goswami *et al*. (1998), who reported that green manuring increases the number of grains per spike.

5. 1000-grain weight (g)

As shown in Table 6 and Figure 8, the 1000-grain weight was not significantly affected by green manuring. The wheat/jantar-sorghum-wheat (T5) system gave the highest (43.72 g) 1000-grain weight, and the wheat-jantar-rice-wheat (T2) system yielded an intermediate height. These results contrast those of Khan *et al*. (1968), who reported that the sowing of leguminous crops in wheat facilitated the development of grain weight.

6. Grain yield (t ha-1)

The final grain yield of a crop is a function of the combination of its individual yield components, which are likely to be influenced by genetic and environmental factors. The data on grain yield per hectare in Table 7 and Figure 9 were significant. The wheat-jantar-mungbean-wheat (T6) system

Table 6. 1000-grain weight of wheat (g) by cropping system.

Individual comparison of treatment		means
	Treatments	Means
T1	wheat-rice-wheat	42.76
T2	wheat-jantar-rice-wheat	41.27
T3	wheat/jantar-rice-wheat	42.04
T4	wheat-jantar-sorghum-wheat	41.48
T5	wheat/jantar-sorghum-wheat	43.72
T6	wheat-jantar-mungbean-wheat	42.40
T7	wheat/jantar-mungbean-wheat	42.52

Table 7. Wheat grain yield (t ha-1) per cropping system.

Individual comparison of treatment		Means
	Treatments	Means
T1	wheat-rice-wheat	4.77e
T2	wheat-jantar-rice-wheat	5.21 bc
T3	wheat/jantar-rice-wheat	5.10 cd
T4	wheat-jantar-sorghum-wheat	5.05 d
T5	wheat/jantar-sorghum-wheat	5.18 bcd
T6	wheat-jantar-mungbean-wheat	5.36 a
T7	wheat/jantar-mungbean-wheat	5.29 ab
	LSD	0.13

Any two means that do not share letters differ significantly at P<0.05.

produced the highest grain yield (5.36 t ha-1), followed by the wheat/jantar-mungbean-wheat (T7) system (5.29 t ha-1). The grain yields of the wheat-jantar–rice-wheat (T2), wheat/jantar-sorghum-wheat (T5), and wheat/jantar-rice-wheat (T3) systems were lower than the treatments above, but these treatments were statistically on par with each other. The grain yield of the wheat-jantar-sorghum-wheat (T4) system was 5.05 t ha-1. The yields in these plots might be linked to exhaustion by the sorghum crop, which depleted the soil in the kharif season. The lowest yield was generated by the wheat-rice-wheat (T1) system (4.77 t ha-1). These results are consistent with those of Somani (1990), Azam and Yousaf (1991), Swarup (1991), and Saleem (1993).

8. Straw Yield

Straw yield (t ha^{-1}) is a function of the accumulated effects of growth parameters, such as tillers m^{-2} and final plant height. The data on straw yield in t ha^{-1} are shown in Table 8 and Figure 10. The straw yield of wheat was affected significantly by various cropping systems. The highest straw yield (6.98 t ha^{-1}) was generated by the wheat- jantar-mungbean-wheat (T_7) system, by the wheat/jantar-rice-wheat (T_3) system (6.91 t ha^{-1}). The wheat/jantar-sorghum-wheat (T_5) and wheat/jantar-rice-wheat (T_2) systems had statistically similar yields. The wheat-jantar-sorghum-wheat (T_4) system effected a straw yield of 6.28 t ha^{-1}, which was on par with treatments above. The wheat–rice-wheat (T_1) cropping system had the lowest straw yield of 5.76 t ha^{-1}, likely because green manuring was not performed in this plot. These results were consistent with those of Muzaffar (1994), Zia et al. (1998), and Saleem (1993), who reported that green manuring increases the straw yield of wheat.

9. Harvest index (%)

Harvest index indicates the productive efficiency of a crop. Higher harvest index values reflect greater efficiency and vice versa. Harvest index was affected significantly by various cropping systems. The highest harvest index (46.28%) was recorded for the wheat jantar mungbean wheat (T_6) cropping system, followed by the wheat rice wheat (T_1), wheat jantar rice wheat (T_2), wheat jantar sorghum wheat (T_4), and wheat/jantar sorghum wheat (T_5) systems (45.29, 44.96, 44.57, and 44.96, respectively) The harvest index of the wheat/jantar rice wheat (T_3) (42.46%) was statistically on par with that of the (T_7) treatment (43.11%).

The results were consistent with those of Muzaffar (1994), who investigated the effects of green manuring on wheat production in a field trial and reported that this might be due to green manuring.

Benefit-cost ratio of different wheat-based cropping systems

The benefit-cost ratios of various cropping systems were calculated and are shown in Table 9. Consequently, net return and BCR were calculated. The T_3 treatment (wheat/jantar-rice-wheat) generated the highest benefit-cost ratio (1.39), followed by the T_2 (wheat-jantar-rice-wheat) (1.37), T_1 (wheat-rice-wheat) (1.33), and T_5 (wheat/jantar-wheat) (1.16) systems. The T_7 (wheat/jantar-mungbean-wheat) and T_4 (wheatjantar-sorghum-wheat) cropping systems generated a BCR of 1.12.

The T_3 (wheat/jantar-rice-wheat) system yielded a net return of Rs. 31360.45 ha^{-1} and a benefit-cost ratio of 1.39. The second-most profitable cropping system was T_2 (wheat-jantar-rice-wheat) generate a net return of Rs. 30401.85 ha^{-1} and a benefit-cost ratio of 1.37. The lowest net return was observed in the T_1 (wheat-rice-wheat) cropping system (Rs. 24721.8 ha^{-1} and and a benefit-cost ratio of 1.33).

There were two sorghum-based cropping systems two treatments, T_4 (wheat-jantar-sorghum-whet) and T_5 (wheat/jantar-sorghum-wheat), which were were compared with each other. The relay cropped jantar (wheat/jantar-sorghum-wheat) gave a higher net return (Rs. 11937.38 ha^{-1}) and benefit-cost ratio of 1.16 than the sequential cropping T_4 (wheat-jantar-sorghum-wheat) system, which gave a net return of Rs. 9415/- ha^{-1}; thus, the sorghum-based cropping systems with relay cropping of jantar were better. The T_7 mungbean-based cropping system (wheat/jantar-mungbean-wheat) gave a net return

Table 8. Wheat straw yield (t ha^{-1}) per cropping system.

Individual comparison of treatment		Means
	Treatments	Means
T1	wheat-rice-wheat	5.76 f
T2	wheat-jantar-rice-wheat	6.39 c
T3	wheat/jantar-rice-wheat	6.91 b
T4	wheat-jantar-sorghum-wheat	6.28 d
T5	wheat/jantar-sorghum-wheat	6.34 c
T6	wheat-jantar-mungbean-wheat	6.22 e
T7	wheat/jantar-mungbean-wheat	6.98 a
LSD		0.06
LSD		

Any two means that do not share letters differ significantly at P<0.05.

Table 9. Wheat harvest index per cropping system.

Individual comparison of treatment		Means
	Treatments	Means
T1	wheat-rice-wheat	45.29 b
T2	wheat-jantar-rice-wheat	44.96 b
T3	wheat/jantar-rice-wheat	42.46 d
T4	wheat-jantar-sorghum-wheat	44.57 bc
T5	wheat/jantar-sorghum-wheat	49.96 b
T6	wheat-jantar-mungbean-wheat	46.28 a
T7	wheat/jantar-mungbean-wheat	43.11 b
LSD		0.71

Any two means that do not share letters differ significantly at P<0.05.

of Rs. 9311/- ha^{-1} and a BCR of 1.13, higher than those of T_6 (wheat jantar mungbean wheat) (Rs. 8837.63 ha^{-1} and 1.122).

Yield and yield parameters of various kharif crops in various cropping systems

The following Kharif crops were grown during the Kharif season, planted after the green manuring of Jantar. All crops were sown at their proper showing times. All inputs for these crops were applied at their recommended rates. The data on yield and yield parameters were recorded and are shown in Table 10.

RICE

Rice was transplanted on July and harvested on November 10 in the first three treatments. The yield and yield parameters were recorded and are discussed below:

1. **Plan height at maturity (cm)**

Plant height at maturity in these treatments ranged from 76.68-80.40 cm. The wheat/jantar- rice-wheat (T_3) system generated the highest plant height (80.40 cm), and the wheat-rice-wheat (T_1) system had the lowest (76.68 cm).

2. Number of plants m^{-2}.

The wheat-jantar-rice-wheat (T2) system produced the highest number of plants m^{-2} (212.33), and the wheat/jantar-rice-wheat (T3) system generated the lowest (207.67).

3. Number of tillers plant $^{-1}$

The highest number of tillers plant^{-1} was obtained with the wheat/Jantar-rice-wheat (T3) system (11.36), and the lowest value was observed with the wheat-rice-wheat (T1) system (11.32).

4. Number of panicle-bearing tillers plant $^{-1}$

The T1 system yielded 9.37 tillers per plant versus 9.43 for the wheat/jantar-rice-wheat (T2) system.

5. Number of spikelets panicle $^{-1}$

The wheat-rice-wheat (T1), wheat-jantar-rice-wheat (T^2), and wheat/jantar-rice-wheat treatments yielded 120.86, 121.63, and 122.30 spikelets panicle $^{-1}$, respectively.

6. 1000-Kernel weight (g)

The wheat-rice-wheat (T1), wheat-jantar-rice-wheat (T2), and wheat/jantar-rice-wheat (T3) systems gave 1000-kernal weights of 17.9, 17.51, and 17.44 gm, respectively.

7. Paddy Yield (t ha $^{-1}$)

The highest paddy yield was obtained in the wheat/jantar-rice-wheat (T3) system which was 4.08 t ha $^{-1}$ versus 3.33 t ha $^{-1}$ for the wheat-rice-wheat (T1) system. The higher paddy yield in the wheat/jantar-rice-wheat (T3) cropping system was attributed to the favorable affects of green manuring and the beneficial effects of the previous crop on soil fertility. The paddy yield in treatment was increased at the expense of improved soil fertility by jantar crops. These results are consistent with those of Furoc et al. (1988), Goswami et al. (1988), John et al. (1989), Balasubramaniyan (1991), and Swarup (1991), who performed field experiments and demonstrated that green manuring jantar increases the paddy yield of rice.

8. Straw Yield (t ha $^{-1}$)

The wheat/jantar–rice-wheat (T3) system produced the highest straw yield (9.23 t ha^{-1}), whereas the wheat-rice-wheat (T1) system gave the lowest (8.93 t ha $^{-1}$).

Goswami et al. (1988) and Mian et al. (1988) reported that green manuring increases the straw yield of rice.

9. Harvest Index (%)

The harvest index reflects the product efficiency of a crop. Higher harvest index values indicate greater efficiency and vice versa. The highest harvest index was recorded in the wheat-jantar-rice-wheat (T2) system. The lowest harvest index was recorded in the wheat-rice-wheat (T1) system.

10. SORGHUM

Sorghum was sown in July in the T_4 and T5 cropping systems for forage purposes. Forage yield and other parameters are discussed below:

Table 10. Yield and yield parameters of various kharif crops in various cropping systems.

Treatments	Plant height at maturity (cm)	Number of Plants m^{-2}	Number of tillers m^{-1}	Number of panicle-bearing tillers $plant^{-1}$ Number of pod $plants^{-1}$	Number of spikiest $panicle^{-1}$ Number of seed pots $^{-1}$	1000- Kernel wt. (g) rice 1000-seed wt. mung.	Paddy yield t ha^{-1} Seed yield t ha^{-1} Forage yield ha^{-1}	Straw yield t ha^{-1}	Harvest index (%)
T_1: Wheat-rice-wheat	78.14	209.33	11.32	9.37	120.86	17.09	3.33	8.93	9.37
T_2: Wheat-jantar-rice-wheat	76.68	212..33	11.33	9.43	121.63	17.51	4.07	9.05	31.02
T_3: Wheat/jantar-rice- wheat	80.40	207.67	11.36	9.42	122.30	17.44	4.08	9.23	30.65
T_4: wheat-jantar-sorghum-wheat	137.00	39.36					37.38		
T_5: Wheat/jantar-sorghum-wheat	137.33	40.93					37.18		
T_6: Wheat-jantar- mungbean-wheat		43.33		23.72	11.05	53.78	0.91	2.904	23.88
T_7: Wheat/jantar-mungbean-wheat		44.33		23.93	11.78	55.17	0.90	3.05	22.78

1) Plant height at maturity (cm)

The plant height of sorghum in these treatments ranged from 137.00 to 137.33 cm in the T_4 and T_5 treatments.

2) Number of Plants m^{-2}

The number of plants m^{-2} of sorghum in the relay crop ((wheat/jantar-sorghum-wheat) was 40.93 versus 39.36 plants per m^{-2} in the sequential crop (wheat-jantar-sorghum-wheat).

3) Forage yield (t ha^{-1})

Forage yield is a function of the combined effects of plant stand and plant height. Wheat-jantar-sorghum-wheat had a higher (37.38 t ha^{-1}) yield, and wheat/jantar-sorghum-wheat had a lower yield (37.18 t ha^{-1}) Kouyot et al. (2002) conducted a field experiment and observed that crop residues and legume rotations increase sorghum yield.

MUNGBEAN

Mungbean was planted on July 17 in the last two treatments. The results are discussed below**:**

1. Number of plants m^{-2}

The wheat-jantar-mungbean-wheat (T6) and wheat/jantar-mungbean-wheat (T7) systems generated 43.33 and 44.33 plants m^{-2}, respectively.

2. Number of pods plant $^{-1}$

The most pods plant $^{-1}$ were recorded in the T7 wheat/jantar-mungbean-wheat system (23.93) versus the lowest value in the T_6 (wheat-jantar-mungbean-wheat) system (23.72 pods plant $^{-1}$).

3. Number of seeds pod $^{-1}$

The number of seeds pod^{-1} is an important factor that directly exploits the potential yield of crops. Table 11 shows that the T7 cropping system (wheat/jantar-mungbean-wheat) gave 11.78 seeds per pod, followed by the T^6 cropping system (wheat-jantar-mungbean-wheat) (11.05 seeds pod $^{-1}$).

4. 1000-seed weight (g)

The wheat/jantar-mungbean-wheat (T_7) system gave 55.17 g in 1000-seed weight, and the wheat-jantar-mungbean-wheat (T_6) system generated 53.78 g in 1000-seed weight.

5. Seed yield (t ha^{-1})

Seed yield is function of the combined effects of individual yield components, which are influenced by various agronomic practices and the environment. The wheat/jantar-mungbean-wheat and wheat-jantar-mungbean-wheat treatments yielded 0.90 t ha^{-1} and 0.91 t ha^{-1} of grains, respectively.

Sharma et al. (2000) conducted similar experiments and demonstrated that green manuring increases the yield of mungbean.

6. Straw yield (t ha^{-1})

The T_6 wheat-jantar-mungbean-wheat and wheat/jantar-mungbean-wheat (T_7) systems produced 2.90 and 3.05 t ha^{-1}, respectively.

1. Harvest index (%)

The wheat/jantar-mungbean-wheat (T6) and wheat-jantar-mungbean-wheat (T7) cropping systems yielded 23.88% and 22.78%, respectively.

SOIL ANALYSIS

Soil analysis was performed twice (shown in Tables 11 and 12)—before the sowing of jantar crop and at the completion of the each cropping system. EC, soil pH, organic matter %age, N %age, available P, available K, and saturation %age were estimated and are shown in Tables 12 and 13. In the T_1 (wheat-rice-wheat) cropping system, EC increased from 0.10 to 0.11 dsm^{-1} and available P rose from 16.0 to 17.1 ppm; the following parameters decreased: soil pH from 8.2 to 8.1, organic matter %age from 1.5 to 1.3%, N content from 0.052 to 0.51%, available K from 160 to 140 ppm, and saturation %age from 32 to 31%. In the T_2 (wheat- jantar-rice-wheat) cropping system, the following values increased on completion: EC from 0.13 to 0.14 dSm^{-1}, organic matter %age from 1.03 to 1.13%, N content from 0.050 to 0.056%, and available P from 16.1 to 16.9 ppm; the values that decreased were: soil pH from 8.2 to 8.1, available K from 180 to 170 ppm, and saturation %age from 33 to 32%. In the T_3 (wheat/jantar-rice-wheat) cropping system, in the following values rose: EC from 0.11 to 0.12 dSm^{-1}, organic matter %age from 0.93 to 1.14, N content from 0.046 to 0.057%, available P from 15.1 to 15.9 ppm, available K from 180 to 200 ppm, and saturation %age from 32 to 33%. In this cropping system, soil pH declined from 8.2 to 8.1. The improvement in soil fertility was likely due to incorporation of organic residues of jantar crop, which was rotavated as a green manure crop.

The T_4 (wheat-jantar-sorghum-wheat) cropping system also had various soil properties affected. The values that increased on completion of the cropping system were: EC from 0.10 to 0.14 and available P from 15.5 to 17.2 ppm. Those that decreased were: soil pH from 8.2 to 8.1, organic matter %age from 1.14 to 1.03%, N content from 0.57 to 0.51%, available K from 180 to 140 ppm, and saturation %age from 34 to 33%. The decrease in organic matter, N content, and available K was likely due to the sorghum crop, which is very exhaustive in nature.

In the T_5 (wheat/jantar-sorghum -wheat) cropping system, the values that increased were EC from 0.12 to 0.13 dSm^{-1} and available P from 15.4 to 16.7 ppm, while saturation %age were remained the same. The following parameters fell: organic matter from 1.10 to 1.04%, N content from 0.055 to 0.052%, pH from 8.2 to 8.1, and available K from 200 to 130 ppm.

In the T_6 (wheat-jantar-mungbean-wheat) cropping system, the values that increased were: EC from 0.11 to 0.15 dSm^{-1}, organic matter %age from 1.02 to 1.13%, N content from 0.051 to 0.056%, available P from 15.5 to 16.8 ppm, and saturation %age from 31 to 33. Those that decreased were soil pH from 8.2 to 8.1 and available K from 165 to 135 ppm.

The T_7 (wheat/jantar-mungbean-wheat) cropping system also had various soil properties affected. EC increased from 0.10 to 0.12 and available P rose from 14.4 to 16.9 ppm. The following values decreased: soil pH from 8.2 to 8.1, organic matter %age from 1.14 to 1.13%, N content from 0.057 to 0.056%, available K from 150 to 140, and saturation %age 32 to 31%.

CONCLUSIONS

A field study was performed at the Postgraduate Agricultural Research Station (PARS), University of Agriculture, Faisalabad, to examine the influence of green manuring jantar (*Sesbania aculeate.* L) on the growth and yield of crops grown in wheat-based cropping systems . Wheat crop of rabi was harvested with a combine harvester. Jantar crop was sown for green manuring; as the relay crop in treatments T_3, T_5, and $T_{7;}$ and as the sequence crop in the T_2, T_4, and T_6 treatments. The various kharif crops were planted after rotavating the jantar crop according to the treatment schedules during the kharif season. Yield and yield parameters of these crops were recorded. In the following rabi season, wheat was planted in all cropping systems. The experiment was laid out in randomized complete block design (RCBD) with three replications. The net plot size was 12 m x 25 m. Physicochemical analysis of the soil was performed before the sowing of green manure crop and on completion of crops grown in different cropping systems. The effects of green manuring and the kharif crops on various parameters and yield of wheat that was planted during the following rabi season were studied. The results are summarized below:

Plant height at maturity, number of tillers m^{-2}, and number of productive tillers m^{-2} were affected significantly in the various cropping systems. The number of plants m^{-2} , number of grains per spike, and 1000-grain weight were not affected significantly. Grain and straw yield were influenced significantly. The highest grain yield (5.36 t ha^{-1}) was recorded in the wheat-jantar-sorghum-wheat cropping system versus the lowest (4.77 t ha^{-1})in the wheat-rice-wheat cropping system. The highest paddy yield of rice was recorded in the T_3 (wheat jantar rice wheat) cropping system compared with the lowest in the T_1 (wheat rice wheat) cropping system.

The T_3 (wheat jantar rice wheat) cropping system was the best cropping system that improved the fertility status of the soil. Minimum effects on soil fertility were observed in the T_1 (wheat rice wheat) cropping system.

Of the various cropping systems, the highest net return (Rs. 31360.45 ha^{-1}) was recorded in the T_3 (wheat /jantar-rice -wheat) cropping system, followed by T_2 (wheat-jantar -rice -wheat) (Rs. 30401.85 ha^{-1}), T_4 (wheat-jantar- sorghum -sorghum wheat) (Rs. 9415/- ha^{-1}), T_7

Table 11. Soil analysis (before sowing of jantar).

Treatments	Depth (cm)	Electric conductivity (EC dSm'1)	Soil pH	Organic matter (%)	Available N (ppm)	Available P (ppm)	Available K (ppm)	Saturation (%)	Texture of Soil
TI: Wheat-rice-wheat	0-15	0,10	8.2	0.83	0.041	16.0	160	32	Loam
T2 : Wheat-jantar-rice- wheat	0-15	0.13	8.2	0.93	0.046	16.1	180	33	Loam
TS Wheat/jantar-rice-Wheat	0-15	0.11	8.2	1.03	0.05	15.1	200	33	Loam
T4 Wheat-jantar-sorghum- Wheat	0-15	0.10	8.2	1.14	0.057	15.5	180	34	Loam
TS Wheat/jantar-sorghum-wheat	0-15	0.12	8.2	1.10	0.055	15.4	200	32	Loam
Te : Wheat-jantar- mungbean- wheat	0-15	0.11	8.2	1.02	0.051	15.5	165	31	Loam
T_7 : Wheat/jantar- mungbean- wheat	0-15	0.10	8.2	1.14	0.05.7	14.4	150	32	Loam

Table 12. soil analysis(after the completion of cropping systems).

Treatments	Depth (cm)	Electric conductivity (EC dSm'1)	Soil pH	Organic matter (%)	A iavailable N (ppm)	Available P (ppm)	Available K (ppm)	Saturation (%)	Texture of Soil
TI: Wheat-rice-wheat	0-15	o.16	8.1	1.04	0.052	19.1	140	31	Loam
T2 : Wheat-jantar-rice-wheat	0-15	0.14	8.1	1.14	0.057	19.9	170	32	Loam
TS Wheat/jantar-rice-Wheat	0-15	0.12	8.1	1.13	0.056	15.9	180	32	Loam
T4 Wheat-jantar-sorghum-Wheat	0-15	0.14	8.1	1.03	0.051	17.2	140	33	Loam
TS Wheat/jantar-sorghum-wheat	0-15	0.13	8.1	1.04	0.052	16.7	130	32	Loam
Te: Wheat-jantar-mungbean-wheat	0-15	0.15	8.1	1.13	0.056	16.8	135	33	Loam
T7: Wheat/jantar-mungbean-wheat	0-15	0.12	8.1	1.12	0.056	16.9	140	31	Loam

Table 13. Economic analysis.

	Cost/ha $^{-1}$ per crop	Total cost of crops	Gross income	Net Return	Benefit Cost ratio
Treatments	(Rs.)				
T_1: Wheat-rice-wheat	16861.11-18115.98-17296.11	74773.20	26250+38295+34950=99495	24721.80	1.33
T_2: Wheat-jantar-rice-wheat	16861.11-5730.42-119180.52-17506.10	81803.15	26285+46805+39150=112205	30401.85	1.37
T_3: Wheat/jantar-rice- wheat	16861.11/4042.33-19194.90-17461.11	80059.55	26250+46920+38250=111420	31360.45	1.39
T_4: wheat-jantar-sorghum-wheat	16861.11-5730.42-10865.47-17442.36	73399.36	26250+18690+37875=82815	9415.00	1.13
T_5: Wheat/jantar-sorghum-wheat	16861.11/4042.43-10857.97-17491.11	71752.62	26250+18590+38850=83690	11937.38	1.16
T_6: Wheat-jantar- mungbean-wheat	16861.11-5730.42-9330.73-17491.11	71913..37	226250+14301+40200=80750	8837.63	1.12
T_7: Wheat/jantar-mungbean-wheat	16861.11/4042.43-9322.85-17506.11	70232.5	26250+14144+39150=79544	9311.00	1.13S

Net income = Total income – Total cost
Benefit-cost ratio = Gross income / Total cost.

(wheat/jantar- mungbean-wheat) (Rs. 9311/- ha^{-1}), and T_6 (wheat- jantar-mungbean-wheat) (Rs. 8837.63 ha^{-1}).

The highest BCR was observed in the T_3 (wheat/ jantar-rice -wheat) cropping system (1.39); the lowest was calculated for T_6 (wheat- jantar-mungbean- wheat) (1.12). Thus, we conclude that the T_3 (wheat/jantar-rice-wheat) cropping system effected the highest net return and benefit-cost ratio.

Therefore, the wheat jantar rice wheat cropping system should be implemented to obtain maximum net returns and improve the fertility status of soil.

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