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Effect of green and brown manuring in maize: Wheat cropping system for higher productivity and soil health in command areas

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Abstract
A field experiment on effect of green and brown manuring in maize – wheat cropping system for higher productivity and soil health in UKP command was studied at Agricultural Research Station, Bheemarayanagudi during *kharif* and *rabi* seasons of 2013-14 and 2014-15 to study. The pooled data indicated that the plots treated with green and brown manuring recorded significantly higher organic carbon, available NPK and dehydrogenase activity compared to control (60 cm X 20cm) without manuring. The grain yield of maize (55.35 q ha^{-1}) was significantly higher with sunnhemp as green manuring in 1:2 row proportions compared to sole maize (60 cm x 20 cm) without manuring (43.85 q ha^{-1}) and it was found on par with sunnhemp, cowpea and dhaincha as brown manuring in 1:1 and 1: 2 row proportions in maize. The residual effect of legume species used as green and brown manuring in preceeding maize was affected significantly on succeeding wheat crop. Sunnhemp as green manuring in 1:2 row proportion registered significantly higher grain yield and straw yield of wheat (38.45 q ha^{-1} and 70.23 q ha^{-1}, respectively.) and it was on par with sunnhemp as brown manuring in 1:2 row proportion. The lowest grain yield (18.35 q ha^{-1}) and straw yield (36.4 q ha^{-1}) were recorded in sole maize plot (60 cm x 20 cm) without manuring in preceeding season. The growth and yield attributing parameters of both the crops were also followed same trend. Varying levels of N did not vary on the performance of wheat. However, higher growth, yield and yield parameters of wheat were recorded in 125 % RDN. The net returns also differed significantly among the green and brown manuring practices under maize – wheat cropping system. Sunnhemp as green manuring in 1:2 row proportion (Rs.89,476 ha^{-1}) followed by sunnhemp as brown manuring 1:2 row proportions (Rs. 85,820 ha^{-1}) and sunnhemp as green manuring in 1:1 row proportions (Rs. 84,575 ha^{-1}) were recorded significantly higher net returns. The lowest net returns (Rs. 45,735 ha^{-1}) were recorded in sole maize (60 cm x 20 cm) - wheat sequence. The different nitrogen levels did not differ.

Keywords: Brown manuring, green manuring, productivity, residual effect, succeeding crop

Introduction
Rice – Rice is the predominant cropping system being adopted by the farmers long back in Upper Krishna and Tunga Bhadra Projects of Karnataka. At present, this cropping system is creating lot of problems with respect to sustainability in crop production and lands are increasingly becoming unproductive. There are some indications of stagnation or even decline in soil fertility and the productivity of this cropping system due to indiscriminate use of water, continuous cropping, decreased soil organic matter, over exploitation of nutrients reserve and loss of nutrients. Of the several options available, adoption of alternate novel crop rotation appears to be promising. Maize has become an alternate crop to be integrated in rice-rice system replacing one rice crop especially during winter or replacing rice - rice by alternate and profitable system involving maize - wheat sequence in the command. Such cropping system needs investigation to explore the possibility of new concepts of agriculture *viz*., green manuring, brown manuring, conservation agriculture, crop nutrition through target yield approach etc. However, use of inorganic fertilizers in combination with green manure and crop residues may improve the soil productivity (Sharma and Prasad, 2001) [11].
Green manuring is a renewable source of input for building up soil fertility and supplementing plant nutrients contained in the biomass. Such biomass can be obtained either by growing *in situ* and incorporated or grown elsewhere and brought in for incorporation in the field as green manuring. However such practice is not popular among the farming community particularly in arable field crops and cropping systems due to more expensive and labours not available in time. At present, a new concept called brown manuring technique is gaining popularity in rice ecosystem. Brown manuring is the practice to reduce weed pressure, as brown manuring acts as a cover crop in suppressing weed growth effectively at the initial growth stage (Kumar and

Mukharjee, 2011) [5]. The post emergence herbicidal spray on green manure leaves results in loss of chlorophyll in leaves leading to browning and hence the same is referred brown manuring (Tanwar *et al*., 2010) [14]. It can be achieved through raising green manure crops such as *Sesbania* (dhaincha), sunnhemp etc., as inter crop and killing the same later by application of post emergence herbicides. The suppressed residue as manure is allowed to remain in the field. But at the same time its use is very much required to enhance the sustained accumulation by improving the soil fertility and supplementing the plant nutrients in arable crops practicing cereal-cereal and cereal-legume cropping systems in rainfed as well as irrigated condition.

Studies of enzyme activities in soil are important as they indicate the potential of the soil to support biochemical processes, which are essential for the maintenance of soil fertility. Any management practice that influences microbial communities in soil may be expected to produce changes in soil enzyme activity level. Soil dehydrogenase activity is often used as a measure of any disruption caused by pesticides, trace elements or management practices. Dehydrogenase are considered to play an essential role in the initial stages of the oxidation of soil organic matter by transferring hydrogen and electrons from substrates to acceptors. Many different intracellular enzymes or enzyme systems contribute to the total dehydrogenase activity.

Keeping these points in view, the present investigation was undertaken to study the effect of green and brown manuring in maize – wheat cropping system for higher productivity and soil health in command areas.

Material and Methods

A field experiment was conducted during *kharif* and *rabi* seasons of 2013-14 and 2014-15 at Agricultural Research Station, Bheemarayanagudi, University of Agricultural Sciences, Raichur, Karnataka. The soil of the experimental site was medium deep black soil with 7.80 pH. The soil was low in available nitrogen (243 kg ha^{-1}), high in available phosphorus (49 kg ha^{-1}) and high in available potassium (337 kg ha^{-1}). The organic carbon content of the soil was low (0.43 %). The Agricultural Research Station represents the UKP command where in rice - rice, chilli and cotton are the predominant crops. The rainfall received during cropping seasons in the year 2013 - 14 and 2014 - 15 was 759 mm and 646 mm respectively. The experiment was laid out in a Randomized Complete Block Design consisting of nine treatments namely M_1 - Control (60 cm x 20 cm) as sole maize, M_2 - Maize + sunnhemp as green manuring (1:1), M_3 - Maize + sunnhemp as green manuring (1:2), M_4 - Maize + sunnhemp as brown manuring (1:1), M_5 - Maize + sunnhemp as brown manuring (1:2), M_6 - Maize + cowpea as brown manuring (1:1), M_7 - Maize + cowpea as brown manuring (1:2), M_8 - Maize + dhaincha as brown manuring (1:1), M_9 - Maize + dhaincha as brown manuring (1:2) during *kharif* season. During *rabi* season, these nine treatments become main plots and sub plots consist of three N levels (75, 100 and 125% RDN) to wheat for which, experiment was laid out in split plot design with three replications. The maize hybrid 900M was sown with the spacing as per the treatments. The spacing followed for green and brown manuring treatments is 90 cm x 20 cm (T_2 to T_9) and 60 cm x 20 cm for control plot as per the recommendations. The recommended dose of fertilizer 150: 75: 37.5 NPK kg ha^{-1} was used for maize. The variety DWR 198 was used for wheat. The fertilizers were applied to wheat as per the treatments. Pre emergent herbicide pendimethalin 30 EC @ 2.5 kg ha^{-1} was used to control weeds in initial stage in maize intercropped with green manure crops. Post emergent herbicide 2, 4 - D 80 % @ 1.25 kg ha^{-1} was used for suppressing the green manure crops and incorporated them as brown manure after harvest of maize in the place where green manure was grown. Other agronomic practices were followed commonly in all the treatments as per the recommendations.

Results and Discussion

Effect of green and brown manuring of legume species on soil enzyme activity, organic carbon, available nutrient status and uptake by crops

Addition of green and brown manures at incorporation did not differ, but relatively increased the dehydrogenase activity over non manured plot during 2013. There was difference among the treatments at incorporation as well as at harvest during 2014 and from pooled mean. The higher dehydrogenase activity was recorded in sunnhemp (73.85µTPF g^{-1} soil day^{-1} average from M_2 to M_5) and cowpea (72.02µTPF g^{-1} soil day^{-1} average from M_6 to M_7 followed by dhaincha (71.02µTPF g^{-1} soil day^{-1} average from M_8 to M_9) compared to non manured plot (69.17 µTPF g^{-1} soil day^{-1}). The similar trend was followed at harvest of maize and at 40 DAS of wheat. Similar findings were reported by Shriramachandrashekaran *et al*. (1997) [13] and Nooli and Chittapur (2001) [6].

The organic content of soil did not show any marked improvement during 2013, but significant differences were observed in the organic carbon content of the soil due to treatments during 2014 and from pooled mean. Incorporation of sunnhemp and cowpea added significantly higher amounts of soil organic carbon (0.47 and 0.46% respectively) and was closely followed by dhaincha (0.45%) when compared to non manured plot. The lowest organic carbon content was observed in non manured treatment (0.39%). The increase in organic carbon content of the soil due to sunnhemp and cowpea incorporation was 17.02 and 15.2 per cent over non manured plot.

The improvement in organic carbon content in the soil could be related to differences in the biomass added by the legumes at the time of incorporation. Similar trends of improvement in organic carbon contents of the soil were reported by Nooli and Chittapur (2001) [6].

The available nitrogen status of the soil due to green and brown manuring did not show any significant differences during 2013. But significant differences were observed due to green and brown manuring of legume species at the time of maize - wheat harvest. The available nitrogen status was maximum in sunnhemp (250.13 kg ha^{-1} average value of M_2 to M_5) and cowpea (243.34 kg ha^{-1} average value of M_6 to M_7) and closely followed by dhaincha (240.77 kg ha^{-1} M_8 to M_9). All these treatments were significantly superior to other legumes. The lowest available N was observed in control (214.07 kg ha^{-1}). The differences in available N in the soil might be attributed to differences in biomass and nitrogen added through green and brown manuring of legume species. The results are in agreement with the findings of Nooli and Chittapur (2001) [6].

The available phosphorus status of the soil did not show any significant difference among the treatments, but differed significantly due to green and brown manuring treatments during 2014 and from pooled mean. The available phosphorus was higher with sunnhemp grown in 1:2 row proportions for green (44.21 kg ha^{-1}) and brown (44.04 kg ha^{-1}) manuring

followed by sunnhemp grown in 1:1 row proportions for green (43.21 kg ha^{-1}) and brown (41.71 kg ha^{-1}) manuring when compared to non manured plot (37.32 kg ha^{-1}). While, cowpea used for green and brown manuring purpose were observed to be next best treatments. The average per cent increase in available phosphorus was around 13.80 per cent over control. The increase in availability of phosphorus might be due to addition of more biomass of legume species through green and brown manuring. The results are in agreement with the findings of Hebbi (2000) and Nooli and Chittapur (2001) [6]. Similar trend was followed for available potassium due to green and brown manuring practices. Similarly, Samant and Patra, (2016) indicated that brown manuring to *kharif* rice fb application of FYM @ 3 t ha^{-1} to *rabi* greengram recorded significantly higher organic carbon (0.47%) and available NPK (217.6, 16.2 and 221.8 kg ha^{-1}) over in initial soil status. The nitrogen uptake by maize and N uptake by wheat at harvest revealed that addition of sunnhemp and cowpea recorded significantly higher values than non green manured sole maize i.e. (60 cm x 20 cm). The higher N uptake by maize and wheat due to green and brown manuring of sunnhemp and cowpea might be due to higher availability of N on decomposition of these legume species. The manuring of sunnhemp, cowpea and dhaincha was increased the N uptake of maize by 17.54 kg ha^{-1}, 9.54 kg $ha^{-1}$and 5.66 kg ha^{-1} respectively over control. Similarly in succeeding wheat crop, residual of effect of theses manuring treatments was increased the N uptake by 32.6 kg ha^{-1}, 24.1 kg $ha^{-1}$and 20.5 kg ha^{-1} respectively. Similar observations were made Nooli and Chittapur (2001) [6] also reported uptake of N by safflower.

Effect of green and brown manuring of legume species on maize

The grain and stover yield of maize did not differ due to green and brown manuring treatments during 2013-14 and differed significantly during 2014-15. This clearly indicated that legumes have positive influence on maize yields when grown as intercrops for green manuring than sole maize. Among all the treatments in the investigation, the green manuring treatments maize + sunnhemp as GM in 1:2 row proportion (M_3) followed by maize + sunnhemp as GM in 1:1 row proportion recorded the highest grain yield of maize of 55.35 and 53.37q ha^{-1} respectively. The increase in grain yield of maize intercropped with sunnhemp in 1:1 and 1:2 row proportions for green manuring purpose was 23.96 per cent over sole maize. Nooli and Chittapur (2001) [6] and Jat *et al.* (2010) [4] also reported similar results.

Among different brown manuring practices, the treatment maize + sunnhemp as BM in 1:2 row proportion recorded higher grain and stover yield (53.40 q ha^{-1} and 67.00 q ha^{-1} respectively) followed by maize + sunnhemp as BM in 1:1 row proportion, maize + cowpea as BM in 1:1 row proportion, maize + cowpea as BM in 1:2 row proportion, maize + dhaincha as BM in 1:1 row proportion and maize + dhaincha as BM in 1:2 proportion. All these treatments were on par with each other and also with maize + sunnhemp as GM in 1:2 row proportions. Further, all these treatments increased the grain yields of maize by 21.78, 19.54, 13.79, 15.89, 9.87 and 11.13 per cent respectively over sole maize (60 cm x 20 cm) which recorded the lowest grain and stover yield (43.85 q ha^{-1} and 50.18 q ha^{-1} respectively). The results are in conformity with the findings of Aslam *et al* (2008) [1], Sharma *et al* (2008) [12] and Satyaprakash and Phoolchand, (2011) [9]. The improvement in grain and stover yield of maize in association with sunnhemp, cowpea and dhaincha grown as intercrops in 1:1 and 1:2 row proportions for green and brown manuring may be further attributed to favourable effect on growth components like plant height, leaf area index and TDMP and yield components such as cob length, cob girth, and number of grains and 100-seed weight which resulted from increased N uptake and dehydrogenase activity. Similar findings were also reported by Ramachandran *et al* (2012) [7]. This result was further corroborated with the findings of Samar Singh *et al* (2007) [10] and Kumar and Mukharjee (2011) [5]. Harvest index did not differ due to the treatments.

Effect of green and brown manuring of legume species on succeeding wheat

With respect to green manuring, sunnhemp in 1:1 and 1:2 row proportion recorded 50.12 and 52.27 per cent higher grain yield of wheat respectively over without green manuring. The findings are in conformity with the findings of Nooli and Chittapur (2001) [6] who studied in maize - safflower sequence cropping. With respect to brown manuring techniques, the maximum grain yield of wheat with brown manuring of sunnhemp in 1:1 (35.71 q ha^{-1}) and 1:2 row proportions in preceding maize (37.79 q ha^{-1}) was noticed. The brown manuring of cowpea grown in 1:1 and 1:2 row proportions in preceding maize was found to be next best treatments. All these treatments recorded significantly higher grain yield over yield obtained with brown manuring of dhaincha in 1:1(25.62 q ha^{-1}) and 1:2 (27.56 q ha^{-1}) row proportions in preceeding maize.

Brown manuring of sunnhemp in 1:1 and 1:2 row proportions recorded 51.44 and 48.61 per cent higher grain yield of wheat over control plot. While brown manuring of cowpea in 1:1 and 1:2 row proportion recorded 42.75 and 46.84 per cent higher yield than control plot. While, brown manuring of dhaincha in maize failed to give satisfactory yield levels of wheat. The information on the effect of brown manuring on succeeding crop is very meager. However, similar kind of influence on succeeding crop was observed with green manuring practice in *kharif* crop. The increase in grain yield could be attributed to numerically higher yield components such as number of tillers, number of grains, grain weight and test weight as affected by residual effect of brown manuring. Grewal *et al* (1992) [3] studied the response of wheat to residual effect of green manuring as much as 0.5 t ha^{-1}. Thus, green manuring augmented total productivity of maize - wheat system by 2.1 t ha^{-1}. The findings of Gangawar *et al* (2004) [2] also confirmed closely with the findings of Jat *et al.* (2010) [4] who observed that the residual effect of sesbania green manuring + wheat straw and sesbania green manuring alone used in preceding maize affected significantly the growth and yield of succeeding wheat. The increase in the grain yield of wheat might be attributed due to increased plant height, leaf area index, total dry matter production, number of effective tillers, and number of grains per spike and test weight resulted from increased N uptake and dehydrogenase activity. Harvest index did not differ due to the treatments.

Different nitrogen levels to wheat crop had no significant difference. Non significant differences for grain and straw yield of wheat were recorded due to interaction of green and brown manuring of legume species and various nitrogen levels.

Effect of manuring techniques on maize equivalent yield and system productivity

The pooled data revealed that maize equivalent yield and system productivity were followed same trend as that of yields obtained with both crops due to treatments. Significantly higher maize equivalent yield was noticed with maize + sunnhemp as GM (1:2) (43.82 q ha^{-1}). The treatments control (60 cm x 20 cm), maize + sunnhemp as BM (1:1), maize + sunnhemp as BM (1:2), maize + cowpea as BM (1:2) were found on par with maize + sunnhemp as GM (1:2) and they were found significantly superior than maize + dhaincha as BM (1:1) and maize + dhaincha as BM (1:2) which were in turn found on par each other. The treatment maize + cowpea as BM (1:1) expressed its yield level on par with maize + sunnhemp as GM (1:1) and maize + sunnhemp as BM (1:1). Significantly the lowest maize equivalent yield was registered with control (60 cm x 20 cm) (20.95 q ha^{-1}) among all the treatments. The various levels of nitrogen did not differ for maize equivalent yield. However, numerically the higher maize equivalent yield was noticed with 125% RDN (37.51 q ha^{-1}) and lowest yield was 75% RDN (35.18 q ha^{-1}). The interaction effect due to manuring treatments as well as varying levels of nitrogen did not differ significantly.

Significantly higher system productivity was recorded with maize + sunnhemp as GM (1:2) (99.17 q ha^{-1}) as compared to control (60 cm x 20 cm), maize + cowpea as BM (1:1), maize + dhaincha as BM (1:1) and maize + dhaincha as BM (1:2). The treatments maize + sunnhemp as GM (1:1), maize + sunnhemp as BM (1:1), maize + sunnhemp as BM (1:2) and maize + cowpea as BM (1:2) were found on par with maize + sunnhemp as GM (1:2). The treatment maize + cowpea as BM (1:1) was found on par with maize + dhaincha as BM (1:1) and maize + dhaincha as BM (1:2) found significantly superior than control (60 cm x 20 cm). Significantly the lowest system productivity was noticed with control (60 cm x 20 cm) (64.80 q ha^{-1}).The different nitrogen levels did not differ significantly. However, 125% RDN was recorded numerically higher system productivity (88.17 q ha^{-1}). The lowest system productivity (85.85 q ha^{-1}) was noticed with 75% RDN. The interaction effect due to manuring treatments as well as varying levels of nitrogen did not differ.

Economics of green and brown manuring in maize – wheat cropping system

The net returns differed significantly among the green and brown manuring practices under maize – wheat cropping system. Green manuring of sunnhemp grown with maize in 1:2 ratio (Rs.89,476 ha^{-1}) followed by brown manuring of sunnhemp grown with maize in 1:2 ratio (Rs.85,820 ha^{-1}) and green manuring of sunnhemp grown with maize in 1:1 ratio (Rs.84,575 ha^{-1}) recorded significantly higher net returns over other legumes used for green and brown manuring purpose. The B:C ratio was also higher with green manuring of sunnhemp grown with maize in 1:2 ratio (2.18) followed by brown manuring of sunnhemp grown with maize in 1:2 ratio (2.08) and green manuring of sunnhemp grown with maize in 1:1 ratio (2.07). Jat *et al*. (2010) [4] also reported higher net returns and B:C with green manuring. The different nitrogen levels did not differ with respect to the economics. The interaction effect due to manuring treatments as well as varying levels of nitrogen did not differ significantly.

Table 1: Organic carbon, available N, P and K of soil in different green and brown manuring crops in maize - wheat cropping system

Treatment	Organic carbon (%) at 90 DAS			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
M_1 - Control (60 cm x 20 cm)	0.41	0.37	0.39	222.50	215.70	219.10	38.60	39.00	38.82	103.33	106.80	105.06
M_2 - Maize + Sunnhemp as GM (1:1)	0.43	0.50	0.47	247.80	258.05	252.90	42.70	46.67	44.67	119.71	122.51	121.11
M_3 - Maize + Sunnhemp as GM (1:2)	0.44	0.50	0.47	251.10	266.90	259.00	43.70	47.67	45.67	122.78	125.31	124.04
M_4 - Maize + Sunnhemp as BM (1:1)	0.43	0.50	0.47	247.20	257.80	252.50	41.00	45.33	43.17	119.32	120.78	120.05
M_5 - Maize + Sunnhemp as BM (1:2)	0.44	0.50	0.47	248.30	263.30	255.80	43.50	47.67	45.58	122.51	124.84	123.67
M_6 - Maize + Cowpea as BM (1:1)	0.43	0.49	0.46	241.60	252.00	246.80	39.50	44.00	41.77	113.92	114.68	114.30
M_7 - Maize + Cowpea as BM (1:2)	0.43	0.50	0.47	245.10	255.30	250.20	40.10	44.33	42.22	114.65	116.22	115.40
M_8 - Maize + Dhaincha as BM (1:1)	0.41	0.48	0.45	240.20	250.00	245.10	39.00	43.33	41.17	111.55	113.08	112.32
M_9 - Maize + Dhaincha as BM (1:2)	0.42	0.48	0.45	241.40	251.30	246.40	39.10	44.00	41.55	111.92	113.47	112.70
S.Em±	0.02	0.02	0.02	9.53	9.10	8.90	1.70	1.35	1.27	6.94	3.84	3.01
C.D. (0.05)	NS	0.07	0.06	NS	29.20	26.30	NS	4.07	3.84	NS	11.62	9.11

NS – Non significant GM – Green manuring, BM – Brown manuring

Table 2: Dehydrogenase activity at incorporation and harvest of maize in different green and brown manuring crops in maize - wheat cropping system

Treatment	Dehydrogenase activity at incorporation (µ TPF g^{-1} soil day^{-1})			Dehydrogenase activity at harvest of maize (µ TPF g^{-1} soil day^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
M_1 - Control (60 cm x 20 cm)	66.33	69.17	67.75	68.23	67.23	67.73
M_2 - Maize + Sunnhemp as GM (1:1)	68.97	78.50	73.73	77.87	76.80	77.33
M_3 - Maize + Sunnhemp as GM (1:2)	69.43	79.33	74.38	78.90	78.17	78.53
M_4 - Maize + Sunnhemp as BM (1:1)	68.30	77.70	73.00	76.63	74.50	75.57
M_5 - Maize + Sunnhemp as BM (1:2)	69.30	79.27	74.28	78.50	77.13	77.82
M_6 - Maize + Cowpea as BM (1:1)	67.10	76.53	71.82	75.20	74.47	74.83
M_7 - Maize + Cowpea as BM (1:2)	67.77	76.67	72.22	75.60	74.50	75.05
M_8 - Maize + Dhaincha as BM (1:1)	67.00	74.97	70.98	73.87	73.20	73.53
M_9 - Maize + Dhaincha as BM (1:2)	67.10	75.00	71.05	74.33	73.33	73.83
S. Em±	2.21	1.93	1.34	1.86	1.89	1.35
C.D. (0.05)	NS	5.63	4.02	5.44	5.51	4.09

NS – Non significant GM – Green manuring, BM – Brown manuring

Table 4: Growth and yield parameters of maize and wheat as influenced by different green and brown manuring practices and nitrogen levels under maize – wheat cropping system (Mean of two years)

Treatment	Maize							Wheat					
	Plant height (cm)	Leaf area index	TDMP (g plant^{-1})	Cob length (cm)	Cob girth (cm)	Grains per cob	Test weight (g)	Plant height (cm)	Leaf area index	TDMP (g plant^{-1})	No of effective tillers	Grains spike^{-1}	Test weight (g)
Main plots (M)													
M_1 – Maize alone (60 cm x 20 cm)	160.53	3.22	288.88	11.47	10.82	272.49	20.30	68.17	0.89	155.49	164.16	30.69	27.99
M_2 - Maize + Sunnhemp as GM (1:1)	188.32	4.22	351.67	13.50	12.98	386.88	24.77	89.41	1.44	195.52	273.03	40.25	40.97
M_3 - Maize + Sunnhemp as GM (1:2)	192.00	4.31	365.17	15.10	14.07	434.53	25.43	98.53	1.59	210.42	316.62	46.13	44.04
M_4 - Maize + Sunnhemp as BM (1:1)	180.53	4.07	348.82	13.13	12.50	356.51	24.73	86.64	1.35	192.39	251.80	38.11	39.85
M_5 - Maize + Sunnhemp as BM (1:2)	188.58	4.24	360.79	14.42	13.33	416.53	25.33	95.48	1.50	203.79	286.73	43.03	41.81
M_6 - Maize + Cowpea as BM (1:1)	177.83	3.82	329.20	12.73	11.90	326.63	23.97	82.44	1.23	181.68	226.01	36.27	36.56
M_7 - Maize + Cowpea as BM (1:2)	178.63	3.90	334.75	12.90	12.18	348.53	24.15	84.46	1.31	187.48	241.06	37.35	37.69
M_8 - Maize + Dhaincha as BM (1:1)	173.77	3.58	316.67	12.08	11.75	312.67	22.85	76.97	1.15	165.05	201.92	32.53	30.24
M_9 - Maize + Dhaincha as BM (1:2)	175.58	3.67	323.57	12.50	11.88	318.30	23.22	79.26	1.21	176.42	213.35	34.71	35.36
S. Em±	6.28	0.21	10.08	0.89	0.52	21.25	0.54	2.37	0.06	4.93	7.10	1.30	1.55
CD (P=0.05)	15.70	0.62	30.49	2.20	1.57	64.27	1.63	7.16	0.18	14.90	21.46	3.94	2.19
Sub plots (N)													
N_1- 75 % RDN	-	-	-	-	-	-	-	83.41	1.17	182.97	235.10	36.58	35.81
N_2- 100 % RDN	-	-	-	-	-	-	-	84.35	1.29	185.74	239.97	37.79	37.42
N_3- 125 % RDN	-	-	-	-	-	-	-	86.02	1.43	187.38	248.82	38.65	38.28
S.Em±	-	-	-	-	-	-	-	1.53	0.03	3.41	2.71	0.53	0.96
CD (P=0.05)	-	-	-	-	-	-	-	NS	0.09	NS	7.81	1.52	NS
Interaction (M x N)	-	-	-	-	-	-	-	NS	NS	NS	NS	NS	NS

Table 5: Grain yield, stover yield (maize), straw yield (wheat) and harvest index and economics as influenced by different green and brown manuring practices and N levels in maize – wheat cropping system (Mean of two years)

Treatment	Maize			Wheat			Maize equivalent yield of wheat (q ha^{-1})	System productivity (q ha^{-1})	Net return (Rs. ha^{-1})	B : C ratio
	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index				
Main plots (M)										
M_1 – Maize alone (60 cm x 20 cm)	43.85	50.18	0.47	18.35	36.49	0.34	20.95	64.80	45735	1.16
M_2 - Maize + Sunnhemp as GM (1:1)	53.37	65.43	0.45	36.79	67.28	0.35	41.94	95.30	84575	2.07
M_3 - Maize + Sunnhemp as GM (1:2)	55.35	70.23	0.44	38.45	70.23	0.35	43.82	99.17	89476	2.18
M_4 - Maize + Sunnhemp as BM (1:1)	52.42	64.68	0.45	35.71	64.41	0.35	40.69	93.11	81581	1.99
M_5 - Maize + Sunnhemp as BM (1:2)	53.40	67.00	0.44	37.79	68.19	0.36	43.08	96.48	85820	2.08
M_6 - Maize + Cowpea as BM (1:1)	49.90	60.68	0.45	32.05	57.44	0.36	36.55	86.45	72595	1.76
M_7 - Maize + Cowpea as BM (1:2)	50.82	62.13	0.45	34.52	63.11	0.35	39.34	90.16	77219	1.86
M_8 - Maize + Dhaincha as BM (1:1)	48.18	56.65	0.46	25.62	45.35	0.36	29.21	77.40	60713	1.48
M_9 - Maize + Dhaincha as BM (1:2)	48.73	58.05	0.46	27.56	49.71	0.35	31.42	80.16	64094	1.55
S.Em±	2.63	3.16	0.02	1.86	2.94	0.02	2.12	3.02	3976	0.10
CD (P=0.05)	6.83	9.57	NS	5.62	8.89	NS	6.41	9.14	12023	0.29
Sub plots (N)										
N_1- 75 % RDN	-	-	-	30.86	55.25	0.36	35.18	85.85	72340	1.78
N_2- 100 % RDN	-	-	-	31.85	59.06	0.35	36.31	86.98	73506	1.79
N_3- 125 % RDN	-	-	-	32.90	60.11	0.35	37.51	88.17	74756	1.81
S.Em±	-	-	-	1.37	1.26	0.01	1.56	1.56	2057	0.05
CD (P=0.05)	-	-	-	NS	3.63	NS	NS	NS	NS	NS
Interaction (M x N)	-	-	-	NS	NS	NS	NS	NS	NS	NS

Note: Maize – Rs 1325/ q (2013-14) and Rs. 1310/q (2014-15), Wheat – Rs.1550/q (2013-14) and Rs. 1450/q (2014-15)
NS – Non significant

Conclusion

Sunnhemp as green manuring in 1:2 row proportion followed by sunnhemp as brown manuring 1:2 row proportions recorded significantly higher grain and stover yield of maize. And also influenced on succeeding wheat crop to produce higher grain and straw yield of wheat. These treatments were known to be get higher net returns (Rs. 89,476 and Rs 85,820 ha^{-1} respectively) and B:C (2.18 and 2.08 respectively) compare to other treatments. Thus, sunnhemp as green manuring in 1:2 row proportion followed by sunnhemp as brown manuring 1:2 row proportions were proved to be very effective to increase the productivity of maize – wheat cropping system under UKP command.

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