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Biomass production and N accumulation of brown and green manuring of legume intercrops on yield, N uptake and economics of maize: Wheat cropping system under UKP command

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Abstract
An investigation was carried out during *kharif* and *rabi* seasons of 2013-14 and 2014-15 at Agricultural Research Station, Bheemarayanagudi to find out the effect of green and brown manuring on yield and N uptake by maize – wheat cropping system under UKP command. Significantly higher biomass (1.67 t ha^{-1}) and N accumulation (55.11 kg ha^{-1}) was recorded with sunnhemp as green manuring in 1:2 ratio followed by sunnhemp as brown manuring in 1:2 ratio compared to other treatments. Sunnhemp recorded higher N content (3.23 to 3.31%) followed by cowpea (3.16 to 3.18%) as compared to dhaincha (2.75 to 2.82%). 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 preceding maize was affected significantly on succeeding wheat crop and maintained same trend as that of maize. Varying levels of N did not vary on the performance of wheat. The maximum uptake of N was noticed with sunnhemp as green manuring in 1:2 row proportion followed by sunnhemp as brown manuring 1:2 row proportions in maize – wheat cropping system. Therefore, these treatments resulted in lesser net loss/ gain in N content in soil. The lowest uptake of N and higher net loss/ gain in N content in soil was recorded in sole maize (60 cm x 20 cm) - wheat sequence. The higher net returns and B:C ratio were observed with these treatments compared to sole maize (60 cm x 20 cm) - wheat sequence.

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

Introduction
Maize – wheat system is predominant cropping system in northern part of our country, covering 60% of area of rainy season maize (Yadav *et al*., 2000) [14]. The contribution of this cropping system to total cereal production is considerably large, being 31% of wheat and 6% of maize. In India the productivity of both maize and wheat is substantially lower than the world average (Economic Survey of India, 2008) [2]. There are some indications of stagnation or even decline in the productivity of this cropping system due to decreased soil organic matter, over exploitation of nutrients reserve, loss of nutrients and non availability of cost effective fertilizer. Further, the application of inorganic fertilizers even in balanced form may not sustain soil fertility and productivity under continuous cropping. However, use of inorganic fertilizers in combination with green manure and crop residues may improve the soil productivity (Sharma and Prasad, 2001) [11].

Nitrogen management is one among the various factors for improving productivity; it plays a vital role by participating in different metabolic activities in plant system. The improved genotypes of cereals and cropping systems need more quantities of nitrogen for full exploitation of their potential to produce the yields. Fertilizer N and bio - sources are the major sources of nitrogen supply for crop. Incorporation of farm waste as biological as well as practice of green manuring in cereals is viable options, which improves the productivity and partially substitutes the fertilizer nitrogen requirement of the subsequent crop. Adequate information is available on the response of maize and wheat to either inorganic or organic fertilizers on single crop. Green manuring is a renewable source of input for building up soil fertility and supplementing plant nutrients contained in the biomass. It has popularized as a low cost effective technology to save on fertilizer and other inputs. However such practice is not popular among the farming community particularly in arable field crops and cropping systems due to non availability of labours in time and more expensive.

At present, a new concept called brown manuring technique is gaining popularity in rice ecosystem. It can be achieved through raising green manure crops such as *Sesbania* (dhaincha), sunnhemp etc., as inter crop and suppressing the same later by application of post emergence herbicides results in brown colour due to loss of chlorophyll in leaves and hence the same is referred brown manuring (Tanwar *et al*., 2010) [13]. 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. However, meager information is available on the use of legume species as intercrops for green and brown manuring in conjunction with N doses in maize - wheat cropping system. Therefore, an attempt has been made to substitute the fertilizer N through green and brown manuring in maize – wheat cropping sequence.

Material and Methods

A field experiment was carried out 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 hybrid 900M was used for maize and the variety DWR 198 was used for wheat. The recommended dose of fertilizer 150: 75: 37.5 NPK ha^{-1} was used for maize. 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

Performance of green and brown manuring legume species

The green and brown manuring legume intercrops differed significantly with respect to their biomass accumulation, N content and N accumulation at the time of manuring at 40 DAS. Significantly higher biomass (1.67 t ha^{-1}) and N accumulation (55.11 kg ha^{-1}) among different legume species were associated with sunnhemp grown with maize in 1:1 and 1:2 row proportions for green manuring and in 1:1 and 1:2 row proportions for brown manuring purpose. Sunnhemp recorded higher N content (3.23 to 3.31%) followed by cowpea (3.16 to 3.18%) as compared to dhaincha (2.75 to 2.82%). The treatments consisting of sunnhemp (51.12 t ha^{-1} average from M_2 to M_5) accumulated significantly higher N than cowpea (35.92 t ha^{-1} average from M_6 to M_7) and dhaincha (30.91 t ha^{-1} average of from M_8 to M_9) which were almost similar in N accumulation.

In this connection, it can be conferred that sunnhemp proved to be superior in biomass production and N accumulation than other legumes and cowpea could be the next best legume with respect to N content.

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) [7].

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) [7].

Similarly, Samant and Patra, (2016) [9] 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 N (217.6 kg ha^{-1}) over in initial soil status.

N uptake and N balance

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. Higher N content (uptake) in produce and higher biomass production of maize and wheat might be the pertinent reasoning for higher uptake of N with these treatments. These findings are in close

agreement with the results reported by Patro *et al* (2005) [8] in respect of maize and Jamwal (2005) [5] in respect of wheat. The data on addition and depletion data and available N content in soil indicated that the maximum gain was found with control due to lower uptake on N at this level. This could be ascribed to the application of green and brown manures. Further, it also indicated that the maximum net loss / gain in N content in soil (kg ha^{-1}) were noticed with increasing N levels without green manuring. 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) [7] also reported uptake of N by safflower.

Effect of manuring of intercrop 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. The similar results are conferred by the findings of Nooli and Chittapur (2001) [7]

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) [10].

Effect of manuring of inter crop 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. Further, this result also corroborated with the findings of Nooli and Chittapur (2001) [7] 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 preceding 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. Grewal *et al* (1992) [4] 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) [3] also confirmed closely with the findings of Jat *et al* (2010) [6] 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.

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 manuring of inter crop legume species on 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) [6] 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: Biomass, nitrogen content and nitrogen accumulation of different green and brown manuring crops in maize - wheat cropping system

Treatment	Biomass (t ha^{-1})			Nitrogen content (%)			Nitrogen accumulation (kg ha^{-1})		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
M_1 - Control (60 cm x 20 cm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M_2 - Maize + Sunnhemp as GM (1:1)	1.54	1.47	1.51	3.25	3.22	3.23	50.21	47.43	48.82
M_3 - Maize + Sunnhemp as GM (1:2)	1.69	1.64	1.67	3.30	3.31	3.31	55.84	54.38	55.11
M_4 - Maize + Sunnhemp as BM (1:1)	1.52	1.47	1.49	3.21	3.21	3.21	48.88	47.14	48.01
M_5 - Maize + Sunnhemp as BM (1:2)	1.63	1.57	1.60	3.28	3.28	3.28	53.36	51.73	52.55
M_6 - Maize + Cowpea as BM (1:1)	1.16	1.10	1.13	3.16	3.16	3.16	36.54	34.65	35.60
M_7 - Maize + Cowpea as BM (1:2)	1.17	1.11	1.14	3.18	3.18	3.18	37.23	35.26	36.24
M_8 - Maize + Dhaincha as BM (1:1)	1.14	1.07	1.10	2.67	2.84	2.75	30.36	30.39	30.37
M_9 - Maize + Dhaincha as BM (1:2)	1.14	1.09	1.12	2.75	2.88	2.82	31.47	31.42	31.44
S.Em±	0.07	0.03	0.04	0.07	0.11	0.06	2.31	2.09	1.51
C.D. (0.05)	0.19	0.08	0.12	0.21	0.33	0.19	6.75	6.09	4.62

GM – Green manuring, BM – Brown manuring

Table 2: 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})		
	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
M_2 - Maize + Sunnhemp as GM (1:1)	0.43	0.50	0.47	247.80	258.05	252.90
M_3 - Maize + Sunnhemp as GM (1:2)	0.44	0.50	0.47	251.10	266.90	259.00
M_4 - Maize + Sunnhemp as BM (1:1)	0.43	0.50	0.47	247.20	257.80	252.50
M_5 - Maize + Sunnhemp as BM (1:2)	0.44	0.50	0.47	248.30	263.30	255.80
M_6 - Maize + Cowpea as BM (1:1)	0.43	0.49	0.46	241.60	252.00	246.80
M_7 - Maize + Cowpea as BM (1:2)	0.43	0.50	0.47	245.10	255.30	250.20
M_8 - Maize + Dhaincha as BM (1:1)	0.41	0.48	0.45	240.20	250.00	245.10
M_9 - Maize + Dhaincha as BM (1:2)	0.42	0.48	0.45	241.40	251.30	246.40
S.Em±	0.02	0.02	0.02	9.53	9.10	8.90
C.D. (0.05)	NS	0.07	0.06	NS	29.20	26.30

Table 3: Nitrogen uptake (kg ha^{-1}) by maize –wheat cropping system and nitrogen balance after completion of cropping system as influenced by different green and brown manuring practices and nitrogen levels

Treatment	N uptake (kg ha^{-1})				Total uptake (kg ha^{-1})		Total available N (Initial + added through fertilizers) (kg ha^{-1})		Available N in soil after harvest (kg ha^{-1})		Net loss/ gain in N content in soil (kg ha^{-1})	
	Maize		Wheat									
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Main plots (M)												
M_1 – Maize alone (60 cm x 20 cm)	141.33	134.67	75.33	104.67	276.0	180.0	393	372.5	222.5	215.7	170.5	156.8
M_2 - Maize + Sunnhemp as GM (1:1)	148.33	161.49	112.33	131.49	309.8	243.8	393	397.8	247.8	258.0	145.2	139.8
M_3 - Maize + Sunnhemp as GM (1:2)	150.33	169.62	114.33	139.62	320.0	254.0	393	401.1	251.1	266.9	141.9	134.2
M_4 - Maize + Sunnhemp as BM (1:1)	148.00	156.50	112.00	126.50	304.5	238.5	393	397.2	247.2	257.8	145.8	139.4
M_5 - Maize + Sunnhemp as BM (1:2)	148.67	161.52	112.67	131.52	310.2	244.2	393	398.3	248.3	263.3	144.7	135.0
M_6 - Maize + Cowpea as BM (1:1)	144.67	146.39	108.67	116.46	291.1	225.1	393	391.6	241.6	252.0	151.4	139.6
M_7 - Maize + Cowpea as BM (1:2)	146.67	150.72	110.67	120.69	297.4	231.4	393	395.1	245.1	255.3	147.9	139.8
M_8 - Maize + Dhaincha as	143.67	140.61	107.67	110.65	284.3	218.3	393	390.2	240.2	250.0	152.8	140.2

BM (1:1)												
M_9 - Maize + Dhaincha as BM (1:2)	144.67	145.75	107.78	115.75	290.4	223.5	393	391.4	241.4	251.3	151.6	140.1
S.Em±	10.30	6.65	10.22	6.66	-	-	-	-	-	-	-	-
CD (P=0.05)	NS	20.12	28.62	20.13	-	-	-	-	-	-	-	-
Sub plots (N)					-	-	-	-	-	-	-	-
N_1- 75% RDN	-	-	102.93	120.16	102.93	120.16	318	317.8	242.8	252	75.2	65.8
N_2- 100% RDN	-	-	106.93	121.91	106.93	121.91	343	342.8	242.8	252	100.2	90.8
N_3- 125% RDN	-	-	110.63	123.91	110.63	123.91	368	367.8	242.8	252	125.2	115.8
S.Em±			0.17	0.04	-	-	-	-	-	-	-	-
CD (P=0.05)	-	-	0.49	0.12	-	-	-	-	-	-	-	-
Interaction (M x N)	-	-	NS	NS	-	-	-	-	-	-	-	-

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

Table 4: Grain yield, stover yield and harvest index of maize and grain yield, straw yield and harvest index of wheat as affected 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})
	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
M_2 - Maize + Sunnhemp as GM (1:1)	53.37	65.43	0.45	36.79	67.28	0.35	41.94	95.30
M_3 - Maize + Sunnhemp as GM (1:2)	55.35	70.23	0.44	38.45	70.23	0.35	43.82	99.17
M_4 - Maize + Sunnhemp as BM (1:1)	52.42	64.68	0.45	35.71	64.41	0.35	40.69	93.11
M_5 - Maize + Sunnhemp as BM (1:2)	53.40	67.00	0.44	37.79	68.19	0.36	43.08	96.48
M_6 - Maize + Cowpea as BM (1:1)	49.90	60.68	0.45	32.05	57.44	0.36	36.55	86.45
M_7 - Maize + Cowpea as BM (1:2)	50.82	62.13	0.45	34.52	63.11	0.35	39.34	90.16
M_8 - Maize + Dhaincha as BM (1:1)	48.18	56.65	0.46	25.62	45.35	0.36	29.21	77.40
M_9 - Maize + Dhaincha as BM (1:2)	48.73	58.05	0.46	27.56	49.71	0.35	31.42	80.16
S.Em±	2.63	3.16	0.02	1.86	2.94	0.02	2.12	3.02
CD (P=0.05)	6.83	9.57	NS	5.62	8.89	NS	6.41	9.14
Sub plots (N)								
N_1- 75% RDN	-	-	-	30.86	55.25	0.36	35.18	85.85
N_2- 100% RDN	-	-	-	31.85	59.06	0.35	36.31	86.98
N_3- 125% RDN	-	-	-	32.90	60.11	0.35	37.51	88.17
S.Em±	-	-	-	1.37	1.26	0.01	1.56	1.56
CD (P=0.05)	-	-	-	NS	3.63	NS	NS	NS
Interaction (M x N)	-	-	-	NS	NS	NS	NS	NS

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

Table 5: Economics of maize - wheat cropping system as influenced by different green and brown manuring practices and nitrogen levels

Treatment	Cost of cultivation of maize – wheat system (Rs. ha^{-1})			Net return (Rs. ha^{-1})			B : C ratio		
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Main plots (M)									
M_1 – Maize alone (60 cm x 20 cm)	39238	39838	39538	62137	29334	45735	1.58	0.74	1.16
M_2 - Maize + Sunnhemp as GM (1:1)	40638	41238	40938	92894	76257	84575	2.29	1.85	2.07
M_3 - Maize + Sunnhemp as GM (1:2)	40842	41442	41142	96335	82617	89476	2.36	1.99	2.18
M_4 - Maize + Sunnhemp as BM (1:1)	40738	41338	41038	90597	72564	81581	2.22	1.76	1.99
M_5 - Maize + Sunnhemp as BM (1:2)	40942	41542	41242	94073	77566	85820	2.30	1.87	2.08
M_6 - Maize + Cowpea as BM (1:1)	40938	41538	41238	83959	61232	72595	2.05	1.47	1.76
M_7 - Maize + Cowpea as BM (1:2)	41210	41810	41510	87057	67382	77219	2.11	1.61	1.86
M_8 - Maize + Dhaincha as BM (1:1)	40888	41488	41188	72319	49107	60713	1.77	1.18	1.48
M_9 - Maize + Dhaincha as BM (1:2)	41143	41743	41443	76017	52171	64094	1.85	1.25	1.55
S.Em±	-	-	-	6072	4561	3976	0.15	0.11	0.10
CD (P=0.05)	-	-	-	18362	13793	12023	0.45	0.33	0.29
Sub plots (N)									
N_1- 75% RDN	40410	41010	40710	82734	61947	72340	2.04	1.51	1.78
N_2- 100% RDN	40731	41331	41031	83866	63147	73506	2.06	1.52	1.79
N_3- 125% RDN	41052	41652	41352	85196	64315	74756	2.07	1.54	1.81
S.Em±	-	-	-	2383	2277	2057	0.06	0.05	0.05
CD (P=0.05)	-	-	-	NS	NS	NS	NS	NS	NS
Interaction (M x N)	-	-	-	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

Green manuring of sunnhemp as legume inter crop 1:2 row proportion followed by brown manuring of sunnhemp as legume intercrop in 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. The uptake of nitrogen could be enhanced due to use of manuring of intercrop legume species. 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 production of maize – wheat cropping system under UKP command.

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