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Effect of fertilization on the biomass production of green manure crops during *rabi* in Southern Telangana Zone

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Abstract
The experiment was conducted to evaluate the performance of various legume green manure crops *viz*., green gram, black gram, horse gram, cowpea, sunhemp, dhaincha, and pillipesara for biomass production at the College farm, College of Agriculture, Rajendra Nagar during *rabi*, 2020-21. The focus of the research was to look at how green manure crops grew in terms of plant height, leaf area, nodule count, and dry matter production up to the 50 percent flowering stage with respect of fertilization. Fertilization to green manure crops with recommended doses certainly had a favourable effect on plant height which increased to the tune of 16.7 cm as against unfertilized conditions (12.2 cm). Fertilization has brought about a significant increase in the leaf area 41.1 & 377 cm^2, respectively) of the green manure crops over the unfertilized treatments at both 30 DAS & 50% flowering stage. In both fertilized and unfertilized crops, the leaf area has increased to about 89% during the 50% flowering stage over that recorded at 30 DAS. The effective nodule count among the green manure crops ranged from 3 to 16 at 30 DAS and 2 to 29 at 50% flowering stage. The fertilization to green manure crops demonstrated a significantly higher number of nodules at both 30 DAS (9) and 50% flowering stage (12) than the unfertilized crops (30 DAS - 7; 50% flowering stage - 10). Fertilization to green manure crops remarkably has increased the total dry weight up to 24.05% over the unfertilized crops. Sunhemp and cowpea proved to be good for *rabi* sowing, with good plant stature, higher leaf area, and much better dry matter production, according to the study's findings.

Keywords: *Rabi*, green manure crops, growth, dry matter

Introduction

Soil is one of the most important environmental factors with indispensable significance in plant physiology (Chludil *et al*., 2008) [1]. Thus, maintaining soil quality is of great importance for crop growth and enhancing productivity. Organic manure is a natural source of nitrogen (N) formation process in the soil. It has been observed that organic manures return essential macro elements including N (2.42%), P (1.51%), and K (0.41%), as well as micronutrients such as magnesium, calcium, sulfur, and manganese to the soil while maintaining its fertility. Of the several organic manuring practices, green manuring was found to be an effective one for sustainable nutrient management suiting intensive agriculture. Green manuring is a practice of turning into the soil un-decomposed green plant tissue. The benefits of green manuring are multifold. It increases soil organic matter, available nitrogen and reduces N losses through leaching and soil erosion. It concentrates nutrients near the soil surface in the available form (Sultani *et al*., 2007) [2]. Green manuring is the most important way to influence topsoil. The soil physical properties that are affected by the incorporation of the green manure include the structure, moisture retention capacity, consistency, and density. Other properties such as porosity, aeration, conductivity, hydraulics, and infiltration are allied to the modifications to the soil structure. Post-harvest decaying roots, stem, and leaves significantly increase macropores in the soil. Therefore, the physicochemical properties of the soil improve. It also influences the soil moisture and temperature dynamics (Sultani *et al*., 2007) [2]**.** The Green manuring and soil fertility transformation are considered synonymous with each other but the success of green manuring is largely dependent upon the quantity of biomass produced and later crops to be grown to exploit upon the elevated soil environment much to the benefit of the crops.

Material and Methods

The study was conducted during *rabi*, 2020-21 at college farm, College of Agriculture, Rajendra Nagar, Hyderabad. The experiment was laid out in a strip plot design and replicated thrice on a clay loam soil with seven green manure crops *viz*., green gram, black gram, horse gram, cowpea, sunhemp, dhaincha and pillipesara. The soil of the experimental site was alkaline in reaction with high organic matter and low soil available nitrogen and high soil available phosphorous and potassium. All the crops were sown in the first week of December. The climate of the experimental region is semi-arid (dry). The mean weekly maximum temperature during the experiment ranged from 27.1℃ to 38.1℃ while the mean weekly minimum temperature ranged from 11.1℃ to 22.6℃. The mean weekly relative humidity during the experiment at 0730 hrs and 1400 hrs fluctuated between 72.9 to 95.7 percent and 22.0 to 53.6 percent, respectively. A total rainfall of 2.3 mm was received during the experiment which did not account to a single rainy day. The mean sunshine hours extended from 5.9 to 14.8 hours day^{-1}. The evaporative demand of the atmosphere as reflected by pan evaporimeter (USWB Class A pan) during the crop growth varied from 2.7 to 7.0 mm day^{-1}. The wind speed stretched from 2.5 kmph to 5.3 kmph. Recommended dose of fertilizers and seed rate for respective green manure crops are mentioned in the Table 1. The objective of the study was to determine effect of fertilization on the growth of green manure crops during *rabi* sowing. During the crop growth period, data concerning to crop growth parameters and indices were recorded at 30 DAS and at 50 percent flowering stage. Plants were randomly selected in the main plot and were duly labelled at the first phase of recording the observations and the same plants were used to record the observations all through the growing period.

Table 1: Recommended dose of fertilizers and seed rate for respective greenmanure crops.

Green manure crops	N – P – K (kg ha^{-1})	Seed rate (kg ha^{-1})
Green gram	20-40-0	30
Black gram	25-50-0	20
Horse gram	25-40-20	25
Cowpea	25-40-20	25
Sunhemp	12.5–40-0	50
Dhaincha	0–30-0	50
Pillipesara	30-60-0	20

Results and Discussion

Plant height

A perusal of the data on the plant heights of green manure crops revealed a significant influence of fertilization at different stages (30 DAS and at 50% flowering). The data on the plant height of green manure crops as influenced by fertilization was presented in Table 2 (a & b). The plant height of green manure crops ranged from 6.2 to 22.3 cm at 30 DAS. Among the green manure crops, sunhemp with a plant height of 22.3 cm registered taller plants, while pillipesara reported the lowest plant height (6.2 cm). The cowpea and dhaincha followed sunhemp with comparable plant heights of 18.5 cm and 19.9 cm, respectively. Fertilization to green manure crops with recommended doses certainly had a favourable effect on plant height which increased to the tune of 16.7 cm as against unfertilized conditions (12.2 cm).

Significantly taller plants (92.3 cm) were maintained by sunhemp at 50% flowering. Whereas, cowpea and dhaincha with plant heights of 51.0 and 47.8 cm were found next best to sunhemp. The pillipesara maintained shorter plants (13.5 cm) among the green manure crops at the 50% flowering stage. The favourable effect of fertilization on the plant height of green manure crops was noted from the greater average plant height (46.8 cm) than that under unfertilized conditions (35.2 cm). Under favourable conditions, the maximum plant heights registered by sunhemp, cowpea, and dhaincha at 50% flowering stage were 92.3, 51.0, and 47.8 cm, respectively during *rabi*. Though the plant heights registered by the above crops in the present study were comparatively less than those reported by Rani *et al.* (2020) [3]. The higher plant heights put forth by these crops contrasting to the remaining green manure crops indicate their potential to thrive well even during the low-temperature conditions of *rabi*.

The data of plant height as influenced by the interaction of green manures with fertilizers indicated that all the green manures registered taller plants under fertilised conditions rather than unfertilized conditions at both 30 DAS and 50% flowering stages (Table 2 (a & b)). Of all the green manure-fertilized/unfertilized combinations, fertilized sunhemp fared well with taller plants at 30 DAS. But at 50% flowering stage either fertilized (102 cm) or unfertilized (82.9 cm) conditions, the sunhemp registered taller plants than the other combinations. Statistically greater plant height exhibited by sunhemp may be pinned to the morphological traits of fibre crops. Of all the green manure crops, pillipesara was found to be sensitive for *rabi* sowing as the plants remained in short stature even at 50% flowering stage. On the other hand, readily accessible nutrients for photosynthate production and less dependence on atmospherically fixed nitrogen might have resulted in the favourable performance of green manure crops in terms of plant height due to fertilization than under unfertilized conditions. The results obtained though contradicted Umali garcia *et al*. (1988) [4] during the initial stages of crop growth who stated no significant difference in the plant height of the inoculated alfalfa supplied with or without nitrogen (N). But the statement seems to be true as the crop growth advanced as noted from the nullified differences between the fertilized and unfertilized sunhemp at 50% flowering stage. Though the positive effect of fertilization on plant height is not specifically mentioned in much of the literature, it can be related to the stimulated above-ground growth of green manure crops, mentioned by several workers due to fertilization (Gates and Wilson, 1974 and Casman *et al*.,1981) [5, 6].

Table 2(a): Plant height at 30 DAS as influenced by the interaction of green manure crops with fertilisation.

Plant height (cm) at 30 DAS			
Treatment	Fertilised	Unfertilised	Mean
M_1: Green gram	16.9	10.8	13.8
M_2: Black gram	17.0	11.0	14.0
M_3: Horse gram	9.46	5.43	7.45
M_4: Cowpea	20.6	16.3	18.5
M_5: Sunhemp	24.8	19.8	19.9
M_6: Dhaincha	23.3	16.5	21.2
M_7: Pillipesara	7.21	5.18	6.19
Mean	16.7	12.2	
	S.Em±	CD (P= 0.05)	
Main plots	0.49	1.49	
Sub plots	0.40	1.20	
(M X S) at same main	0.82	2.48	
(M X S) at different sub	1.77	7.63	

Table 2(b): Plant height at 50% flowering stage as influenced by the interaction of green manure crops with fertilisation.

Plant height (cm) at 50% flowering stage			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	33.1	20.7	26.9
M_2: Black gram	33.9	22.4	28.1
M_3: Horse gram	33.3	21.6	27.5
M_4: Cowpea	56.5	45.5	51.0
M_5: Sunhemp	102	82.9	92.3
M_6: Dhaincha	52.9	42.6	47.8
M_7: Pillipesara	15.8	11.2	13.5
Mean	46.7	35.3	
	S.Em±	CD (P= 0.05)	
Main plots	1.31	3.93	
Sub plots	1.63	4.58	
(M X S) at same main	2.42	7.04	
(M X S) at different sub	6.06	26.0	

Leaf area
The data on the leaf area of green manure crops due to fertilization was presented in table 3 (a & b). The leaf area of green manure crops varied significantly due to fertilization at different growth stages.

Initially, at 30 DAS, the leaf area of green manure crops was as high as 81.2 cm^2 in cowpea and as low as 8.41 cm^2 in pillipesara. Sunhemp recorded a leaf area of 49.0 cm^2 following cowpea. Fertilization to green manure crops resulted in a significant increase in leaf area up to an extent of 41.0 cm^2 as compared to unfertilized conditions.

A similar trend extended to the 50% flowering stage. The leaf area of all the green manure crops at 50% flowering stage showed a robust increase ranging from 81.4 to 91.2 percent over that observed at 30 DAS. The cowpea was found highly vigorous among the green manure crops with a greater leaf area of 920 cm^2 at 50% flowering stage. This was followed by sunhemp with a leaf area of 622 cm^2. The lowest leaf area (45.3 cm^2) among the green manure crops was noted in pillipesara. Fertilization has brought about a significant increase in the leaf area (377 cm^2) of the green manure crops over the unfertilized treatments at 50% flowering stage. In both fertilized and unfertilized crops, the leaf area has increased to about 89% during the 50% flowering stage over that recorded at 30 DAS.

The interaction of green manure crops with fertilization was significant for leaf area at all the stages of observation (Table 3 (a & b)). Initially at 30 DAS, the cowpea either fertilized (89.3 cm^2) or unfertilized (73.1 cm^2) showed equivalent leaf area and was higher than the other green manure-fertilized/unfertilized combinations. However, as the crop reached 50% flowering stage, the differences became more prominent resulting in superior stand of fertilized cowpea (1005 cm^2) over the other combinations with regards to leaf area.

More leafiness of all the green manure crops at 50% flowering stage compared to 30 DAS indicates the active vegetative growth of the crops. Though sunhemp registered taller plants, the leafiness was found to be high in the less short crop, cowpea. The sunhemp with taller plants, longer internodes, and greater stem diameter has more lignin in the stem portion resulting in decreased leafiness. The same is supported by Solanki and Patel (1998) [7]. Also, Perry and Larsen (1974) [8] observed a reduction in the number of internodes per stem and individual internodal length and thereby increase in the leafiness which can be related to the increased canopy expanse of cowpea than the other crops in the present study. Little growth contrived by pillipesara despite fertilization indicates its poor adaptability to the low-temperature conditions during *rabi*. Further, early access to nutrients in adequate amounts, saving the energy spent on nodule fixation and N_2 fixation due to fertilization might have increased the leafiness of green manure crops to assimilate the absorbed nutrients. An increase in leaf area with the application of N fertilizer was also noted by Campbell *et al*. (1977) [9].

Table 3(a): Leaf area at 30 DAS as influenced by the interaction of green manure crops with fertilisation.

Leaf area (cm^2) at 30 DAS			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	30.1	27.2	28.7
M_2: Black gram	35.3	30.9	33.1
M_3: Horse gram	34.9	25.6	30.2
M_4: Cowpea	89.3	73.1	81.2
M_5: Sunhemp	53.0	44.9	49.0
M_6: Dhaincha	36.4	29.7	33.0
M_7: Pillipesara	8.67	8.15	8.41
Mean	41.1	34.2	
	S.Em±	CD (P= 0.05)	
Main plots	1.65	4.62	
Sub plots	0.92	2.77	
(M X S) at same main	2.39	6.95	
(M X S) at different sub	4.40	18.9	

Table 3(b): Leaf area at 50% flowering stage as influenced by the interaction of green manure crops with fertilisation.

Leaf area (cm^2) at 50% lowering stage			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	218	167	**192**
M_2: Black gram	224	194	209
M_3: Horse gram	215	192	203
M_4: Cowpea	1005	834	920
M_5: Sunhemp	629	615	622
M_6: Dhaincha	303	254	279
M_7: Pillipesara	48.4	42.3	45.3
Mean	377	328	
	S.Em±	CD (P= 0.05)	
Main plots	13.60	40.80	
Sub plots	7.90	23.70	
(M X S) at same main	19.90	59.70	
(M X S) at different sub	37.30	160.0	

Nodule count
Nitrogen fixation of green manure legumes was studied in terms of effective nodule count and nodule weight. The effective nodule count in green manure crops is an inherent character and varied significantly among the crops during both the stages of study (30 DAS and 50% flowering stage). Further, fertilization also had a notable effect on nodule count at both the stages. Their interaction effect was also significant and was presented in the tables 4 (a & b).

The effective nodule count among the green manure crops ranged from 3 to 16 at 30 DAS and 2 to 29 at 50% flowering stage. The greater number of nodules accommodated in sunhemp at both growth stages indicated the crops' rapid growth and development of enough carbon sources that have met the energy needs of bacteria residing in nodules resulting in a higher effective nodule count. The next best crop with a comparably higher nodule count was cowpea (14). The crops, green gram (3) and black gram (3) being of short duration; while pillipesara (3) with poor growth might have produced less number of nodules which eventually exhausted for the early vegetative growth and establishment of these crops. Following the exhaustion of N reserves in the nodules, the carbon source put up by these crops might not be sufficient enough for the production of excessive nodules as can be seen from the nodule count at 50% of flowering in green gram, black gram, horse gram, and pilli pesara. The fertilization to green manure crops demonstrated a significantly higher number of nodules at both 30 DAS (9) and 50% flowering stage (12) than the unfertilized crops (30 DAS - 7; 50% flowering stage - 10). Balanced addition of nutrients to the green manure crops must have provided the best gain of nitrogen from the plants soil system. Adequate NPK seemed not to have reduced in nitrogen fixed by the symbiosis. Gates and Wilson (1974) [5] reported that with the soils of low fertility the strategic application of nitrogen in addition to superphosphate may strongly provide growth without determinant to nodulation and symbiotic nitrogen fixation. Similar results were obtained by Sistachs (1970) [13]; and Rosas and Bliss (1986) [14]. Sensitivity of nodulation especially to non-optimal levels of combined nutrients was also reported by De Franca *et al*. (1973) [15], Gates and Muller (1979) [16], Cassman *et al*. (1981) [6], Hernandez and Focht (1985) [17], Lynd and Ansman (1989, 1990) [18, 19], and Tsail *et al*. (1993). On the other hand, the presence of nodules in the unfertilized plants suggested that there were native soil rhizobia that were able to infect the roots of the host but not enough to produce a significant improvement in the growth (Mweetwa *et al*., 2016).

Significant difference in the nodule count in response to the interaction of green manure crop with fertilization was noticed at 30 DAS and 50% flowering stage. Initially at 30 DAS, the fertilized cowpea (16) and fertilized (18) and unfertilized (14) sunhemp being at par registered higher nodule number than the other treatment combinations. However, at 50% flowering both fertilized (32) and unfertilized (26) sunhemp alone stood best among the green manure fertilized/unfertilized combination with higher nodule number. As a fast-growing species, though the nitrogen reserves tend to exhaust rapidly the N-supplied as an external source might have reflected with a subsequent positive effect on nodule development in sunhemp (Indieka 2005) [22].

Table 4(a): Nodule count at 30 DAS stage as influenced by the interaction of green manure crops with fertilisation**.**

Nodule count at 30 DAS			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	4.00	2.00	3.00
M_2: Black gram	4.00	2.00	3.00
M_3: Horse gram	6.00	4.00	5.00
M_4: Cowpea	16.0	12.0	14.0
M_5: Sunhemp	18.0	14.0	16.0
M_6: Dhaincha	12.0	10.0	11.0
M_7: Pillipesara	4.00	2.00	3.00
Mean	9.00	7.00	
	S.Em±	CD (P= 0.05)	
Main plots	0.36	0.79	
Sub plots	0.24	0.74	
(M X S) at same main	0.53	1.76	
(M X S) at different sub	1.27	3.96	

Table 4(b): Nodule count at 50% flowering stage as influenced by the interaction of green manure crops with fertilisation.

Nodule count at 50% flowering stage			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	2.00	1.00	2.00
M_2: Black gram	2.00	1.00	2.00
M_3: Horse gram	4.00	2.00	3.00
M_4: Cowpea	21.0	15.0	18.0
M_5: Sunhemp	32.0	26.0	30.0
M_6: Dhaincha	18.0	16.0	17.0
M_7: Pillipesara	6.00	6.00	6.00
Mean	12.0	10.0	
	S.Em±	CD (P= 0.05)	
Main plots	0.60	1.31	
Sub plots	0.37	1.12	
(M X S) at same main	0.84	2.70	
(M X S) at different sub	2.64	8.04	

Dry matter accumulation (kg ha^{-1})

Dry matter partitioning towards, roots, stems and leaves were studied at 30 DAS and 50% flowering stage. Dry matter partitioning was found to be significantly influenced due to fertilization at both stages. The data on dry matter partitioning to roots, stems, and leaves at 30 DAS and 50% flowering stage was presented in the table 5 and 6.

The dry weights of roots, stems, and leaves increased to the tune of 8.09-50.0, 22.2-73.5 and 44.6-65.1 percent, respectively from 30 DAS to 50% flowering stage among the green manure crops. The apportioning of total plant dry matter at 30 DAS was in the range of 16.0-27.1, 42.0-54.4, and 23.7-38.5 percent to the roots, stems, and leaves, respectively. However, at 50% flowering stage, the partitioning of biomass to the roots seems to have reduced slightly, while the apportioning to the leaves and stems was gradual. The total dry matter partitioning was in the range of 12.7 to 18.3, 43.7 to 57.5 and 29.8 to 40.8 percent to the roots, stems, and leaves, respectively in the green manures crops at 50% flowering stage. Fertilization to green manure crops remarkably has increased the total dry weight up to 24.1 percent over the unfertilized crops. From the dry matter data at 30 DAS, it is noted that the allocation was more to the leaves and stems than roots in the case of both fertilized and unfertilized crops. However, the rate of the partitioning of total dry matter to the root (20.5%) and stems (52.5%) was more in unfertilized crops than the fertilized crops (Root-19.0%, and stem-51.8%), while the leaf dry matter partitioning was more in fertilized crops (29.0%) than the unfertilized crops (27.1%). The partitioning of dry matter at the 50% flowering stage was matching and gradual in both fertilized and unfertilized crops (Root-14.9%, stem-50.1%, and leaf- 35.0%).

The root dry weight was exceptionally high in sunhemp with dry weight of 216 kg ha^{-1} at 30 DAS. This was followed by the cowpea with a dry weight 203 kg ha^{-1}. On the other side, the lowest root dry weight was noted with pillipesara (22.5 kg ha^{-1}) and dhaincha (32.1 kg ha^{-1}). However, at 50% flowering stage, sunhemp outperformed the other green manure crops and maintained higher root dry weight (286 kg ha^{-1}) indicating that the crop was vigorous in exploring soil resources. The cowpea followed sunhemp with a root dry weight of 221 kg ha^{-1}. Contrasting to this, pillipesara, due to its poor growth, has allocated the lowest dry matter to the roots 50% flowering stage (30.1 kg ha^{-1}). Fertilizer application to the green manures has influenced the crop growth as seen from the increased dry matter content in the roots both at 30 DAS and at 50% flowering stage. An increase of 28 percent of root dry weight has been observed as the crop growth passed from 30 DAS to 50% flowering stage. The root system plays an important role in the growth and development of the crop and root growth is closely related to the shoot growth, both of which are affected by nutrient availability in the soil (Chen *et al*., 2020) [10]. Under the fertilized condition, quick acquisition of nutrients meeting the nutrient demands of the shoots might have their assimilation and hence dry matter production, and in turn allocation to the roots resulting in higher root dry weight value of the green manure crops at both the growth stages.

Similar to root dry weights, shoot dry weights also were significantly highest with sunhemp (564 kg ha^{-1}) at 30 DAS. But as the crop growth advanced to 50% flowering stage, sunhemp put up more growth with an increased shoot dry weight of 880 kg ha^{-1}. The higher shoot dry weight of sunhemp over the other green manure crops may be related to its plant height. The sunhemp plants owing to their morphological trait as fibre crop grew taller accommodating higher dry weights over the other crops. The cowpea followed sunhemp with a dry weight of 700 kg ha^{-1}. On the other side, the retarded growth of pillipesara with the shortest plants has put forth the lowest shoot dry weights at both 30 DAS (34.8 kg ha^{-1}) and 50% flowering stage (72 kg ha^{-1}) than the other green manure crops. Fertilization to the green manure crops has brought up a significant increase in shoot dry weight than the unfertilized crops at 30 DAS (Fertilized -273; Unfertilized - 209 kg ha^{-1}) and 50% flowering stage (Fertilized-470; Unfertilized- 358 kg ha^{-1}). Application of recommended dose of N, P_2O_5 and K_2O to the green manure crops might have resulted in first-hand availability of nutrients for assimilation and biomass production thus clipping off diversion of some of the carbon source for nodule formation and nitrogen fixation. Hence, the increased biomass production has caused both lateral and vertical expansion of crops through translocation of the photosynthates resulting in greater shoot dry weight values under fertilized conditions.

Initially, at 30 DAS, the leaf dry weight was maximum with sunhemp (291 kg ha^{-1}) followed by cowpea (221 kg ha^{-1}). But as the crop reached 50% flowering stage, cowpea surpassed sunhemp and registered significantly higher leaf dry matter (634 kg ha^{-1}). Extensive canopy development with maximum leaf area during the vegetative growth stage in cowpea as discussed in section 4.1.1.2 of this chapter might have resulted in scoring high leaf dry matter by the end of the 50% flowering stage. Of all the green manure crops, pillipesara was found inferior in piling up dry matter due to poor growth and development during *rabi*. Ease of access to nutrients especially nitrogen during 30 DAS might have resulted in increased leaf dry weight (152 kg ha^{-1}) to the tune of 28.9 percent due to fertilization over the unfertilized crops. The stocking of leaf dry weight continued up to 50% flowering stage ending with an increase in leaf dry weight to a mark of 24.5 percent due to fertilization.

The interaction of green manure crops with or without fertilizer was found to be significant both at 30 DAS (Table 7 (a), (b) and (c)) and 50% flowering stage (Table 7 (d), (e), (f)) during *rabi*. Among the different green manure-fertilized/unfertilized combinations, dry matter partitioning to roots and leaves was equivalent and higher with fertilized cowpea (30 DAS-251 kg ha^{-1}; 50% flowering-283 kg ha^{-1}), fertilized sunhemp (30 DAS-222 kg ha^{-1}; 50% flowering-296 kg ha^{-1}) and unfertilized sunhemp (30 DAS-211 kg ha^{-1}; 50% flowering stage-276 kg ha^{-1}) at both 30 DAS and 50% flowering stage. These combinations also were found to pile up higher dry matter in shoots at 50% flowering stage (Fertilized cowpea-872 kg ha^{-1}; Fertilized sunhemp-882 kg ha^{-1}; Unfertilized sunhemp-877 kg ha^{-1}). But at the earlier stage (30 DAS), fertilized cowpea (554 kg ha^{-1}) and fertilized sunhemp (643 kg ha^{-1}) alone accounted to higher dry weight of the shoots. The marked increase in dry weight of plant tops and roots with the addition of fertilizers (N-P-K) was also reported by Gates and Wilson (1974) [5] in stylo, Kyei Boahen *et al*. (2017) [11] in cowpea and Mintah *et al*. (2020) [12] in cowpea and groundnut, confirms the best performance of fertilized cowpea in the present study. However, fertilization probably had no effect on dry matter accumulation in sunhemp as the biomass apportioning to the roots, stems and leaves though variable initially, remained equivalent under fertilized and under fertilized conditions at 50%f lowering stage.

Table 5: Dry matter accumulation and partitioning in green manure crops as influenced by fertilisation at 30DAS

Treatment	30 DAS						
	Dry matter accumulation (kg ha^{-1})				Dry matter partitioning (%)		
	Root	Stem	Leaf	Total	Root	Stem	Leaf
Green manure crops							
M_1: Green gram	59.2	181	115	355	16.7	50.9	32.4
M_2: Black gram	60.6	182	110	353	17.2	51.6	31.3
M_3: Horse gram	42.5	143	80.0	266	16.0	54.0	30.0
M_4: Cowpea	203	509	221	934	21.8	54.5	23.7
M_5: Sunhemp	216	564	291	1071	20.2	52.6	27.2
M_6: Dhaincha	32.1	77.0	69.0	178	18.0	43.5	38.5
M_7: Pillipesara	22.5	34.8	26.0	83.0	27.1	42.0	30.9
SE(m)±	4.73	11.20	6.15	18.8	-	-	-
CD (P = 0.05%)	10.3	24.3	13.4	40.9	-	-	-
Fertilisation							
S_1-Fertilised	100	273	152	526	19.0	52.0	29.0

S_2-Unfertilised	81.7	209	108	400	20.5	52.4	27.1
SE(m)±	1.39	5.10	3.04	9.78	-	-	-
CD (P = 0.05%)	6.0	21.9	13.0	32.8	-	-	-
Interaction							
(MXS) at same mean							
S.Em±	6.84	15.40	9.01	25.80	-	-	-
CD (P= 0.05)	22.4	49.3	29.8	72.9	-	-	-
Interaction							
(MXS) at different sub							
S.Em±	13.7	48.0	30.3	78.90	-	-	-
CD (P= 0.05)	58.8	151.0	91.7	220.0	-	-	-

Table 6: Dry matter accumulation and partitioning in green manure crops as influenced by fertilisation at 50% flowering stage

Treatment	**At 50% flowering**						
	Dry matter accumulation (kg ha^{-1})				**Dry matter partitioning (%)**		
	Root	**Stem**	**Leaf**	**Total**	**Root**	**Stem**	**Leaf**
Green manure crops							
M_1: Green gram	97	405	254	755	12.8	53.5	33.5
M_2: Black gram	95	365	233	694	13.7	52.6	33.6
M_3: Horse gram	68	184	165	418	16.3	44.1	39.5
M_4: Cowpea	221	700	634	1555	14.2	45.0	40.7
M_5: Sunhemp	286	880	526	1692	16.9	52.0	31.0
M_6: Dhaincha	64	292	151	507	12.6	57.5	29.8
M_7: Pillipesara	30.1	72	63	165	18.2	43.7	38.0
SE(m)±	6.57	22.30	15.80	40.40	-	-	-
CD (P= 0.05)	14.3	48.5	34.4	88.1	-	-	-
Fertilisation							
S_1-Fertilised	139	470	330	939	14.80	50.05	35.14
S_2-Unfertilised	107	358	249	714	14.99	50.14	34.87
SE(m)±	2.27	17.10	7.39	30.50	-	-	-
CD (P= 0.05)	9.8	52.2	31.8	92.7	-	-	-
Interaction							
(MXS) at same mean							
S.Em±	8.26	28.90	18.20	48.30	-	-	-
CD (P= 0.05)	24.5	87.70	48.9	135.0	-	-	-
Interaction							
(MXS) at different sub							
S.Em±	69.2	308.0	174.0	145.0	-	-	-
CD (P= 0.05)	8.26	28.9	18.2	405.0	-	-	-

Table 7(a): Dry matter accumulation by the root at 30 DAS as influenced by the interaction of green manure crops with fertilisation

Dry matter accumulation by the root at 30 DAS (kg ha^{-1})			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	63.2	55.1	59.2
M_2: Black gram	66.5	54.7	60.6
M_3: Horse gram	49.2	35.8	42.5
M_4: Cowpea	251	156	203
M_5: Sunhemp	222	211	216
M_6: Dhaincha	34.3	29.8	32.1
M_7: Pillipesara	26.1	18.9	22.5
Mean	100	81.7	
	S.Em±	CD (P= 0.05)	
Main plots	4.73	10.30	
Sub plots	1.39	6.00	
(M X S) at same main	6.84	22.50	
(M X S) at different sub	13.70	58.80	

Table 7(b): Dry matter accumulation by the stem at 30 DAS as influenced by the interaction of green manure crops with fertilisation

Dry matter accumulation by the stem at 30 DAS (kg ha^{-1})			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	208	153	181
M_2: Black gram	204	160	182
M_3: Horse gram	169	118	143
M_4: Cowpea	554	464	509
M_5: Sunhemp	643	485	564
M_6: Dhaincha	98.0	57.0	77.0
M_7: Pillipesara	38.0	31.0	35.0

Mean	273	210	
	S.Em±	CD (P= 0.05)	
Main plots	11.20	24.30	
Sub plots	5.10	21.90	
(M X S) at same main	15.40	49.30	
(M X S) at different sub	48.00	151.0	

Table 7(c): Dry matter accumulation by the leaf at 30 DAS as influenced by the interaction of green manure crops with fertilisation

Dry matter accumulation by the leaf at 30 DAS (kg ha^{-1})			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	141	89.0	115
M_2: Black gram	130	91.0	110
M_3: Horse gram	98.0	61.0	80.0
M_4: Cowpea	285	158	221
M_5: Sunhemp	304	278	291
M_6: Dhaincha	79.0	58.0	69.0
M_7: Pillipesara	28.3	22.9	25.6
Mean	152	108	
	S.Em±	CD (P= 0.05)	
Main plots	6.15	13.40	
Sub plots	3.04	13.00	
(M X S) at same main	9.00	29.80	
(M X S) at different sub	30.30	91.70	

Table 7(d): Dry matter accumulation by the root at 50% flowering stage as influenced by the interaction of green manure crops with fertilisation.

Dry matter accumulation by the root at 50% flowering stage (kg ha^{-1})			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	106	88.0	97.0
M_2: Black gram	106	84.0	95.0
M_3: Horse gram	80.0	56.9	68.2
M_4: Cowpea	283	160	221
M_5: Sunhemp	296	276	286
M_6: Dhaincha	69.0	59.2	64.0
M_7: Pillipesara	32.8	27.5	30.1
Mean	139	107	
	S.Em±	CD (P= 0.05)	
Main plots	6.57	14.3	
Sub plots	2.27	9.80	
(M X S) at same main	8.26	24.50	
(M X S) at different sub	23.10	69.20	

Table 7(e): Dry matter accumulation by the stem at 50% flowering stage as influenced by the interaction of green manure crops with fertilisation.

Dry matter accumulation by the stem at 50% flowering stage (kg ha^{-1})			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	465	344	405
M_2: Black gram	409	321	365
M_3: Horse gram	235	133	184
M_4: Cowpea	872	528	700
M_5: Sunhemp	882	877	880
M_6: Dhaincha	339	244	292
M_7: Pillipesara	85.0	59.2	72.0
Mean	470	358	
	S.Em±	CD (P= 0.05)	
Main plots	22.3	48.5	
Sub plots	17.1	52.2	
(M X S) at same main	28.9	87.7	
(M X S) at different sub	98.0	308.0	

Table 7 (f): Dry matter accumulation by the leaf at 50% flowering stage as influenced by the interaction of green manure crops with fertilisation

Dry matter accumulation by the leaf at 50% flowering stage (kg ha^{-1})			
Treatment	**Fertilised**	**Unfertilised**	**Mean**
M_1: Green gram	306	201	254
M_2: Black gram	271	196	233
M_3: Horse gram	202	128	165

M_4: Cowpea	690	577	634
M_5: Sunhemp	599	452	526
M_6: Dhaincha	173	130	151
M_7: Pillipesara	69.0	56.4	63.0
Mean	330	249	
	S.Em±	CD (P= 0.05)	
Main plots	15.80	34.40	
Sub plots	7.39	31.80	
(M X S) at same main	18.20	48.90	
(M X S) at different sub	50.40	174.0	

Conclusion

From the observations made in the study, it can be concluded that amongst all the green manure crops grown, sunhemp and cowpea were the best in terms of plant height (92.3 cm, 51 cm), leaf area (622 cm^2, 920 cm^2), nodule count (29, 18) and dry matter production (1692 kg ha^{-1}, 1552 kg ha^{-1}), respectively. Thus, these crops can be recommended for *rabi* sowing in the Southern Telangana Zone.

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