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Suitability of legume green manures for biomass and seed production during *rabi* sowing in Southern Telangana Zone

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Abstract
An experiment was conducted at the College farm, College of Agriculture, Rajendranagar during *rabi*, 2020-21 in order to assess selected legume green manure crops *viz*., green gram, black gram, horse gram, cowpea, sunhemp, dhaincha and pillipesara for biomass and seed production during *rabi*. The study aimed to analyze the growth of the green manure crops in terms of plant height, leaf area, nodule count, dry matter production and seed yield during the growth period. Plant behavioural trait of diminishing growth towards the end of the growing season was noted in all the green manure crops. An overview of the leaf area measured indicated that in all the green manure crops leaf area increased at an increasing rate up to 60 DAS, at a diminishing rate from 60 to 90 DAS, and thereafter decreased towards maturity. The nodule number in the green manure crops increased up to 60 DAS and thereafter decreased as the crop reached maturity. The leaf dry weights behaved in a sigmoidal manner as maximum values reached at 60 DAS in all the green manure crops while the stem and total dry matter accumulation showed a linear function. The results from the study revealed the crops sunhemp and cowpea proved to be exceptionally good for *rabi* sowing with good plant stature, higher leaf area and significantly higher dry matter production and seed yields.

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

Introduction
With the increasing challenges in agriculture, in terms of climate change, extreme weather events, soil degradation and land contamination by the over use of agricultural chemicals, the use of green manures has come into the picture. Growing of green manure crops on the farm land proves to be a practical and economical method to secure long-term productivity of farmed lands as these crops prepare the soil for subsequent crops. These are grown and turned into the soil in order to restore the productivity of the exhausted land. Green manures are a gift from nature as they improve the soil physical, chemical and biological properties and reduce the fertilizer N requirements for the succeeding crops.

Further, short duration legume green manure crops which are generally incorporated in to the soil at 50 percent flowering stage can be explored to get some additional income through seed production and then incorporating the green manure crop residues after taking the harvest. This may ensure green manure seed availability for the next season sowing besides enriching the soil through residue incorporation. Most of the green manure crops are fitted into rice based cropping systems during pre-*kharif* system. In those regions where most of the times the fields are kept fallow, in such regions *rabi* legume green manures can be grown by improving the soil quality along with providing seed as well as income. Keeping all this in view, the present work was planned to study the suitability of legume green manures for biomass and seed production during *rabi* sowing in Southern Telangana Zone.

Material and Methods
The study was conducted during *rabi*, 2020-21 at College farm, College of Agriculture, Rajendranagar, Hyderabad. The experiment was laid out in a randomized block design (RBD) 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 low organic matter and soil available nitrogen and high soil available phosphorous and potassium.

All the crops were sown in the second fortnight of November. The mean maximum temperature varied from 26.4 ℃ to 38.1℃ and the mean minimum temperature varied from 11.1 ℃ to 18.9 ℃ during the growth period of the crops. The relative humidity at morning (RHI) varied from 75.3 to 95.7 per cent, where it was 22 to 60 per cent in the evening. The bright sunshine hours (BSH) varied from 5.1 to 14.8. The velocity of wind ranged from 2.5 to 4.7 kmph during the growing season. The pan evaporation ranged from 2.4 to 6.8 mm. 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 the growth of the green manure crops in terms of plant height, leaf area, nodule count, dry matter production and seed yield. During the crop growth period, data concerning to crop growth parameters and indices were recorded at 30, 60, 90 DAS and at harvest. 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. All the green manure crops in the study were statistically analysed only for dry matter production and seed yield as the remaining crop growth characters are genetically governed traits.

Table 1: Seed rate (kg ha^{-1}) and RDF for the green manure crops

Green manure crops	N-P_2O_5-K_2O (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

Plant height is a central part of plant ecological strategy and is strongly correlated with crop duration, growth, and yield. It is a major determinant of a species ability to compete for available resources (Moles *et al*., 2009) [5].

All the green manure crops exhibited a maximum increase in plant height at 60 DAS which was found to be 49 to 80 percent of the plant height at 30 DAS (Table 2.). The plant height of sunhemp shoots up exceptionally up to 80 percent of the that at 30 DAS whereas, in the remaining crops, the increase in plant height was in the range of 49.6 to 63.3 percent of that at 30 DAS. Plant behavioral trait of diminishing growth towards the end of the growing season was noted in all the green manure crops. The maximum plant height at harvest was 156 cm for sunhemp and the minimum was that of pillipesara with a height of 21.4 cm. Sunhemp being a fiber crop with taller stems had exhibited greater plant height till harvest whereas, pillipesara owing to its morphological stature remained short throughout the study. The difference in plant height between the green manure crops may also be attributed to the genetic variability and environmental adaptability of the crops used in the study. The results conform with those reported by Samant (2014) [8].

Table 2: Plant height (cm) of different green manure crops during *rabi*

Treatments	Plant height (cm)			
	At 30 DAS	At 60 DAS	At 90 DAS	At Harvest
M1: Greengram	10.8	24.2	30.4	34.0
M2: Blackgram	12.6	25.0	29.2	33.4
M3: Horsegram	7.25	18.1	32.4	37.9
M4: Cowpea	16.5	44.9	115	121
M5: Sunhemp	15.0	78.0	141	156
M6: Dhaincha	20.5	43.0	87.0	96.1
M7: Pillipesara	6.66	13.3	18.7	24.4
SEm±	0.48	1.51	3.13	2.16
CD (p=0.05)	1.47	4.66	9.64	6.64
CV%	6.51	7.44	8.37	5.20

Leaf area

The importance of leaf area to basic plant metabolic processes, such as photosynthesis and respiration is generally recognized (Alvaro Bueno, 1979) [3]. The leaf area of green manure crops is directly attributed to the dry matter accumulated which is a prime characteristic that any green manure crop should possess. The leaf area exhibited by the green manure crops in the present study reported significant variations at different stages of growth and is presented in Table 3.

An overview of the leaf area measured indicated that in all the green manure crops leaf area increased at an increasing rate up to 60 DAS, at a diminishing rate from 60 to 90 DAS, and thereafter decreased towards maturity. Leaf area typically increases after crop emergence to a maximum and then declines (Watson, 1947) [12]. However, black gram and sunhemp were exceptional among the green manure crops to put forth maximum leaf area only up to 60 DAS which later decreased towards harvest. Though sunhemp registered taller plants up to 90 DAS, the same was not reflected in establishing leaf area indicating less expanse of the canopy with the increase in plant height that could be attributed to the characteristics of a fibre crop. On the other hand, black gram being a sensitive pulse crop had displayed lesser growth as seen from its plant height and leaf area.

Table 3: Leaf area (cm^2) of different green manure crops during *rabi*

Treatments	Leaf area (cm^2)			
	At 30 DAS	At 60 DAS	At 90 DAS	At Harvest
M1: Greengram	21.2	157	186	20.4
M2: Blackgram	28.4	223	154	23.3
M3: Horsegram	23.0	173	314	23.2
M4: Cowpea	53.0	728	866	56.1
M5: Sunhemp	38.0	698	538	54.7
M6: Dhaincha	31.0	101	146	32.0
M7: Pillipesara	11.4	30.3	45.5	26.8
S.Em±	1.31	7.24	6.35	1.45
CD (p=0.05)	4.03	22.3	19.6	4.46
CV%	7.70	4.16	3.42	7.42

From the above observations, it can be understood that cowpea and sunhemp were most suitable to raise as green manure crops with the highest leaf area compared to other green manure crops (green gram, black gram, horse gram, dhaincha and pillipesara) during *rabi*. Despite low temperatures ranging from 17.1 to 18.9 ^{0}C during the crop growing season, cowpea and sunhemp had put forth leaf areas ranging from 538 cm^2 to 866 cm^2 contributing significantly enough to dry matter accumulation.

Nodule count

The nodule numbers noted at regular intervals during the crop growth showed significant differences between the green manure crops (Table 4.).

The nodule number in the green manure crops increased up to 60 DAS and thereafter decreased as the crop reached maturity. However, sunhemp is an exception which showed an increase in nodule count up to 90 DAS. Nodule formation begins approximately 2–3 weeks after sowing, but it may take longer depending on environmental conditions. Nodule numbers and N_2-fixation rates generally peak during the early- to the mid-flowering stage (Voisin *et al*. 2003) [11] and slow down with the onset of pod filling (Bethlenfalvay and Phillips 1977; Salon *et al*. 2001) [2, 7].

Table 4: Effective nodule count of different green manure crops during *rabi*

Treatments	Nodule count			
	At 30 DAS	At 60 DAS	At 90 DAS	At Harvest
M1: Greengram	10	20	16	6
M2: Blackgram	8	12	7	3
M3: Horsegram	7	10	8	4
M4: Cowpea	12	16	11	8
M5: Sunhemp	14	25	41	16
M6: Dhaincha	4	6	5	2
M7: Pillipesara	3	5	4	1
S.Em±	0.15	0.29	0.25	0.13
CD (p=0.05)	0.47	0.90	0.76	0.40
CV%	3.15	3.73	3.25	3.93

An increase in nodule number up to 60 DAS in a diminishing rate specified that the fixation of nitrogen and utilization in the green manure crops was less confirming that the initial 30 days of sowing is critical for nodule formation in all the green manure crops during *rabi*. Also, in all the crops under the study due to their shorter crop duration, the nodule activity might be high during the early crop growth periods supplementing the crops with required nitrogen. Nevertheless, nodule senescence towards the harvest of the crops may be related to the metabolic switch of carbon sink to nutrient sources due to the death of plants upon aging of the crop (Theophile Kazmierczak *et al*., 2020) [10]. The findings corroborate those of Chowdhury *et al*. (1997) [4], who found that nodules were higher in inoculated plants during the blooming stage, followed by pod filling, and pre-flowering. Patel and Patel also came up with similar findings (1991) [5].

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

The dry matter partitioning is the product of the flow of assimilates from the source organs (leaves and stems) along the transport route to the storage organs (grains). Dry matter accumulation by different parts of the plant at various stages (30, 60, 90, and at harvest) of crop growth differed significantly in different green manure crops as depicted in Table 5. An overview of dry matter accumulation has indicated that the leaf dry weights behaved in a sigmoidal manner as maximum values reached at 60 DAS in all the green manure crops and thereafter decreased, which might be associated with the translocation of assimilates to the grains, the senescence and the leaf fall (Ahmad Khan and Shad Khan Khalil, 2010) [1]. On the other hand, the stem and total dry matter accumulation showed a linear function, which could be associated with the continuous building of dry matter. The higher dry matter accumulation after the reproductive stage was the result of an increase in dry matter of stem and pods, whose continuous gain occurred as a result of increased plant height and no. of branches (Surya *et al*., 2004) [9]. Intercepted radiation and increasing canopy closure (data not shown) can explain differences in total dry matter production between species, as well as the fact that erect leaves utilize light more efficiently than lax leaves because smaller leaf angles reduce light saturation (Wilson, 1960) [13].

Table 5: Dry matter partitioning (kg ha^{-1}) of different green manure crops during *rabi*

Treatments	Dry matter partitioning (kg ha^{-1})															
	30 DAS				60 DAS				90 DAS				Harvest			
	Root	Stem	Leaf	Total	Root	Stem	Leaf	Total	Root	Stem	Leaf	Total	Root	Stem	Leaf	Total
M1: Greengram	11.2	26.8	90.4	128	30.4	114	174	318	112	500	250	862	134	600	200	934
M2: Blackgram	15.8	66.9	96.9	180	52.7	145	203	401	110	509	216	835	132	611	173	917
M3: Horsegram	18.5	34.3	162	215	17.2	101	167	285	113	542	258	913	135	651	206	992
M4: Cowpea	38.3	136	327	501	151	570	757	1478	762	2092	1955	4809	915	2511	1564	4990
M5: Sunhemp	36.1	94.6	315	446	252	570	738	1560	1039	3710	2280	7029	1247	4451	1824	7522
M6: Dhaincha	4.58	14.3	46.4	65.3	68.0	170	238	476	385	1627	449	2461	463	1953	359	2774
M7: Pillipesara	4.42	13.5	25.9	43.8	15.6	93.2	143	252	68.3	415	136	619	75.3	468	126	669
SEm±	0.37	1.21	3.14	5.56	4.73	9.40	17.7	23.9	9.5	35.2	20.2	58.4	10.2	38.6	14.2	70.8
CD (p=0.05)	1.13	3.72	9.67	17.1	14.6	29.0	54.6	73.6	29.3	108	62.3	180	31.3	119	43.6	218.2
CV%	3.44	3.79	3.58	4.27	9.78	6.47	8.88	6.08	4.45	4.54	4.42	4.04	3.97	4.16	3.86	4.57

Conclusion

From the observations made in the study, it can be concluded that amongst all the legume green manure crops grown in *rabi*, sunhemp and cowpea were the best in terms of plant height (156 cm, 121 cm), leaf area (538 cm^2, 866 cm^2), nodule count (41,16) and dry matter production (7552 kg ha^{-1}, 4990 kg ha^{-1}), respectively. Thus, sunhemp and cowpea are the best legume green manure crops that can be recommended for *rabi* sowing in the Southern Telangana Zone with high biomass and seed yield and are also found to be remunerative.

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