MICROBIAL AND ECONOMIC STUDIES OF SUPER EARLY PIGEONPEA UNDER DIFFERENT SOWING DATES AND INTEGRATED NUTRIENT MANAGEMENT IN SOUTHERN TELANGANA ZONE

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PERFORMANCE OF SUPER EARLY PIGEONPEA IN DIFFERENT SOWING WINDOWS AND INTEGRATED NUTRIENT MANAGEMENT IN SOUTHERN TELANGANA ZONE

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ABSTRACT

A field experiment was conducted at Regional Agricultural Research Station, Palem, Nagarkurnool, Southern Telangana Agro Climatic Zone of Telangana State during *kharif* 2018-19 and 2019-20 to study the performance of super early pigeonpea in different sowing windows and with integrated nutrient management practices under rainfed situations. The experiment was laid out in strip plot design for pigeonpea in *kharif* 2018 and 2019 with 3 main treatments *i.e.,* M_1 (1st July), M_2 (20th July) and M_3 (10th August) and four integrated nutrient management practices as sub treatments *viz.,* S_1: 75% RDF, S_2: 75% RDF + FYM enriched with microbial consortia (1 tonne ha^{-1}), S_3: 100 % RDF and S_4: 100% RDF + FYM enriched with microbial consortia (1 tonne ha^{-1}) and replicated thrice. The performance of the super early pigeonpea in two years of field study revealed that, among the three sowing dates in main treatments, 1st July *i.e.,* M_1 witnessed higher final plant population (per cent) and growth parameters *viz*., plant height (cm), leaf area per plant (cm^2) and dry matter production (g m^2) at 30, 60 and 90 DAS. The highest seed, haulm yield (kg ha^{-1}) and harvest index of pigeonpea were superior with 1st July (M_1) compared to the other sowing dates *i.e.,* 20th July and 10th August. In the sub treatments application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) reported highest plant height at different stages of crop growth that resulted highest dry matter accumulation at 30, 60 and 90 DAS among the sub treatments in the both the years. The seed and stover yield were significantly higher with the above treatment and was followed by the application of 100% RDF (S_3). The interaction between sowing dates and integrated nutrient management was found non significant.

Keywords: Enriched FYM, growth attributes, microbial consortia, seed and stover yield, super early pigeonpea

Pigeonpea (*Cajanus cajan* L.) is the sixth most important grain legume in the world and second most important pulse crop after chickpea in India. 90% of the world's cultivated area of pigeonpea is present in India and it is grown in an area of 4.43 M ha and produces 4.25 MT with average productivity of 960 kg ha^{-1} in India. Maharashtra, Madhya Pradesh, Karnataka, Gujarat, and Telangana account for India's 82.2% of the area and 84.9% of the production, In Telangana state; pigeonpea occupies 0.33 M ha and contribute 0.26 M tonnes with productivity of 797 kg ha^{-1} (Agricultural Statistics at a Glance, 2018).

Though highest (>90%) area is present in India, the productivity is low as pigeonpea is seldom grown as sole crop in India and non availability of fast growing, short duration, high yielding photo insensitive pigeonpea cultivars. The available medium and long duration pigeonpea cultivars grown under rainfed conditions were experiencing terminal drought at flowering due to cessation of the south west monsoon in October leads to lower productivity in India. The photo and thermo sensitivity of existing pigeonpea cultivars is also another drawback restricting the horizontal expansion to different cropping systems in varied agro ecologies. Traditional cultivars of pigeonpea are of early (120 to 140 days), medium (140 to 160 days) and long duration (>160 days) types which cannot fit in preceding or succeeding crop situations of rainfed and irrigated ecology. Super early pigeonpea varieties developed from ICRISAT are of 100 days duration with yield potential of 1.0 to 1.5 tonnes ha^{-1} (Vales *et al*., 2012). Yield maximization of super early pigeonpea and its cropping system depends on optimum time of sowing and its succeeding crop. Hence it is necessary to standardize the optimum date of sowing of super early photo insensitive pigeonpea cultivars.

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Besides, fertilizers are becoming costlier and difficult for the resource - poor farmers to apply recommended dose of fertilizers. Hence, integrated nutrient management with microbial consortia consisting of *Rhizobium, Pseudomonas putida*, *Pseudomonas fluorescens* and *Bacillus cereus* enhanced plant biomass and yields of pigeon pea (Tilak *et al.,* 2006). In addition to that, plant growth promoting mycorrhiza like *Rhizobium* spp., can promote plant growth and productivity as primary effect and their role in reducing disease as secondary effect. Hence judicious use of microbial consortia with inorganic sources of nutrients is essential to minimize the cost of inputs, increase the yield and maintain soil health.

MATERIAL AND METHODS

A field trial was conducted at Regional Agricultural Research Station, Palem, Nagarkurnool, Southern Telangana Agro Climatic Zone of Telangana State during *kharif,* 2018-19 and 2019-20 to study the performance of super early pigeonpea in different sowing windows and with integrated nutrient management practices. The experimental site is situated at about 16Ú 51' N latitude and 78º25' E longitude with an average altitude of 478 m above the mean sea level. The soil of experimental site was sandy clay loam with pH 6.7, electrical conductivity 0.34 dSm^{-1}, low organic carbon (0.52%), low available nitrogen (201.3 kg ha^{-1}) and medium phosphorus (16.7 kg ha^{-1}) and high in potassium (309.4 kg ha^{-1}). In *kharif,* crop was sown with three sowing dates as main treatments *i.e.,* M_1 (1st July), M_2 (20th July) and M_3 (10th August) and four integrated nutrient management practices as sub treatments *viz.,* S_1: 75% RDF, S_2: 75% RDF + FYM enriched with microbial consortia (1 tonne ha^{-1}), S_3: 100% RDF and S_4: 100% RDF + FYM enriched with microbial consortia (1 tonne ha^{-1}) in strip plot design with three replications.

Super early photo insensitive cultivar ICPL 20325 pigeonpea is non determinate type (NDT) and it comes to maturity in 90-100 days to open the avenue to explore during the off season and in non-traditional eco systems (Shruthi *et al.,* 2020). This photo insensitive crop is being hardy and early fits in rice fallows, wheat-pulses and sugarcane-pulses intercropping system using residual moisture for growth and development (Hingane *et al.,* 2018). The seeds @ 10 kg ha^{-1} was hand dibbled at the rate of 2 seeds per hill by adopting spacing of 45 x 15 cm in *kharif* season. Farm yard manure enriched with microbial consortia @ 1 tonne ha^{-1} was applied and incorporated into soil one week before sowing as per the treatments. The recommended doses of fertilizer (RDF) for pigeonpea *i.e*., 20:50:0 kg NPK ha^{-1} was applied through urea and single super phosphate (SSP) respectively. Entire N and P_2O_5 were applied basally by placement and covered with the soil. Other cultural operations and plant protection measures were followed as per the recommendations. The data on growth parameters *i.e.,* plant height, leaf area $plant^{-1}$, dry matter accumulation was taken at 30, 60 and 90 DAS. The seed and stover yield taken on net plot basis. The replicated data was statistically analysed in strip plot design and the analysis of variance was calculated using ANOVA table. The experiment was conducted under rainfed situations. The rainfall distribution during the crop period of pigeonpea sown on July 1st (M_1) received 326 mm in 24 rainy days in 2018 and 539.4 mm in 43 rainy days in 2019. The pigeonpea crop sown on July 20th (M_2) utilized 263.4 mm rainfall in 18 rainy days in 2018 and 437.2 mm rainfall in 32 rainy days in 2019. Finally, August 10th sown pigeonpea recorded 247.2 mm rainfall in 15 rainy days in 2018 and 330.0 mm in 29 rainy days in 2019. The dry spells recorded were two, three and four for the July 1st (M_1), July 20th (M_2) and August 10th (M_3) sown pigeonpea crop in the 2018. Whereas in 2019, pigeonpea sown on different dates experienced no distinct dry period during the crop growth. Protective irrigation of 50 mm (each irrigation) was given during the dry period occurred during the crop growth period of pigeonpea. In 2018 for July sown pigeonpea (M_1) two protective irrigations of 50 mm each given at active growth stage (30 DAS) and at initiation of flowering (60 DAS), in July 20th sown (M_2) pigeonpea crop saved with three protected irrigations at crop establishment stage (10 DAS), flowering initiation stage (50 DAS) and pod development stage (80 DAS). Similarly, the August 10th sown (M_3) pigeonpea was provided with four life saving irrigations at active growth stage (30 DAS), initiation of flowering (60 DAS) and two irrigations at pod development stages (one at 90 DAS and another at 100 DAS). The crop was harvested on 22nd October, 7th November and 23rd November in 2018 and 29th October, 11th November and 28th November in 2019 for the three different sowing dates *i.e.,* July 1st, July 20th and August 10th respectively.

RESULTS AND DISCUSSION

Growth parameters

Plant population

During both the years of field study the initial plant population (Table 1) of pigeonpea crop was not significantly influenced by different sowing dates and integrated nutrient management and ranged between 97.0 to 98.0 per cent. Significant variation in the final plant population was noticed with the different sowing dates but not with the integrated nutrient management practices in the both the years of study.

In the year 2018-19, significantly highest final plant population was recorded by the July 1st (94.2) sown and it was on par with the July 20th (93.3) sowing and significantly superior over the August 10th (91.7) sown pigeonpea crop. Whereas in 2019-20, final plant population in July 1st (92.8) sowing was significantly superior over the July 20th (90.6) and August 10th (88.9) sowing dates. The pooled results also followed the similar trend recorded in the 2019-20. The variation in the final plant stand in pigeonpea crop might be influenced by the weather parameters like quantity and intensity of rainfall and availability of soil moisture in the experimental plot. The rainy season catches its peaks of precipitation in the late July and August months of the two years. This enables the soil to have continuous availability of soil moisture and even to excessive soil moisture lead to lose plant population through wilt from the sowing stage to 75% pod maturity of pigeonpea. Similar results were confirmed by Dasharath *et al.* (2012) in the chickpea during *rabi* season. The weather parameter like maximum and minimum temperature influenced the plant population with changed sowing dates in the experiment. The insignificant difference in the integrated nutrient management practices might due to the inorganic fertilizers integrated with organic manures increased the availability of nutrients to the crop throughout the crop growth period.

Table 1. Effect of dates of sowing and INM on plant population (per cent) of super early pigeonpea

Treatments	Initial			Final		
	2018	2019	Pooled mean	2018	2019	Pooled mean
Main treatments (Dates of Sowing)						
M_1 - 1st July	99.1	96.9	98.0	94.2	92.8	93.5
M_2 - 20th July	99.0	95.9	97.5	93.3	90.6	92.0
M_3 - 10th August	98.8	95.3	97.0	91.7	88.9	90.3
SE m (±)	0.18	0.63	0.39	0.24	0.36	0.19
CD (P=0.05%)	NS	NS	NS	0.96	1.42	0.74
Sub treatments (INM)						
S_1 - 75 % RDF	98.7	95.8	97.3	93.0	90.6	91.8
S_2 - 75 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	99.3	95.5	97.4	93.2	90.3	91.8
S_3 - 100 % RDF	99.0	96.0	97.5	93.1	90.8	91.9
S_4 - 100 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	98.9	96.9	97.9	93.1	91.4	92.2
SE m (±)	0.34	0.56	0.30	0.57	0.4	0.25
CD (P=0.05%)	NS	NS	NS	NS	NS	NS
Interaction effect						
Main at same level of sub						
SE m (±)	0.47	0.86	0.47	0.69	1.06	0.70
CD (P=0.05%)	NS	NS	NS	NS	NS	NS
Sub at same level of Main						
SE m (±)	0.39	0.87	0.51	0.57	0.88	0.56
CD (P=0.05%)	NS	NS	NS	NS	NS	NS

Plant height (cm)

Plant height is an important growth index for the accumulation of dry matter by the plant and is very important to monitor the overall canopy architecture and also govern the orientation of the leaves that further govern the photosynthetic efficiency of a plant to utilize the natural resources.

The data on plant height recorded at 30, 60 and 90 DAS of pigeonpea as influenced by the different date of sowing and integrated nutrient management practices were presented in Table 2. A perusal of data showed that plant height was comparatively higher in the second year *i.e.,* 2019-20 as compared to the first year (2018-19). It was found that the periodic plant height of the crop went on increasing till maturity and the magnitude of increase was more than double from 30-60 DAS to harvest irrespective of treatments. From the pooled data on plant height of pigeonpea, it was revealed that as the plant growth progressed, the plant height of pigeonpea significantly higher with July 1st sowing date (M_1) from 30 DAS up to harvest stage. Among sub treatments (integrated nutrient management), application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) produced taller plants as the crop aged from 30 DAS up to harvest.

The results revealed that the plant height at 30 DAS, was much higher with July 1st (M_1) sowing date *i.e.,* 34.1 cm, 36.0 cm in 2018 and 2019 over the plant height recorded in August 10th sowing (31.1 and 33.3 cm) and statistically on par with the July 20th sowing date (33.1 and 34.7 cm). As the crop grew at 60 DAS, significantly taller plants were noticed with July 1st (95.4 and 100.4 cm) and was significantly superior over the plant height observed at July 20th (95.9 cm) during 2019 and August 10th (81.6 and 93.5 cm) dates of sowing during the both the years. Likewise, 90 DAS also, significantly greater plant height

Table 2. Effect of dates of sowing and INM on plant height (cm) of super early pigeonpea

Treatments	30 DAS			60 DAS			90 DAS		
	2018	2019	Pooled mean	2018	2019	Pooled mean	2018	2019	Pooled mean
Main treatments (Dates of Sowing)									
M_1 - 1st July	34.1	36.0	35.1	95.4	100.4	97.9	109.3	122.7	116.0
M_2 - 20th July	33.1	34.7	33.9	88.1	95.9	92.0	100.2	117.1	108.7
M_3 - 10th August	31.1	33.3	32.2	81.6	93.5	87.5	98.4	109.0	103.7
SE m (±)	0.6	0.5	0.2	2.5	0.9	1.0	2.1	1.1	0.8
CD (P=0.05%)	2.2	1.9	0.7	9.7	3.4	4.0	8.4	4.3	3.2
Sub treatments (INM)									
S_1 - 75 % RDF	31.0	32.2	31.6	83.9	92.0	87.9	98.2	108.9	103.5
S_2 - 75 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	32.0	33.6	32.8	86.0	94.8	90.4	100.4	114.0	107.2
S_3 - 100 % RDF	33.3	35.5	34.4	88.6	97.7	93.1	104.7	118.1	111.4
S_4 - 100 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	34.7	37.3	36.0	95.1	101.8	98.5	107.4	124.2	115.8
SE m (±)	0.7	0.7	0.5	1.2	1.6	0.6	1.8	2.8	1.0
CD (P=0.05%)	2.4	2.3	1.7	4.2	5.6	2.0	6.4	9.9	3.33
Interaction effect									
Main at same level of sub									
SE m (±)	1.2	1.4	0.9	3.4	2.6	2.0	4.1	3.2	2.3
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub at same level of Main									
SE m (±)	1.0	1.2	0.7	3.4	2.1	1.8	3.7	2.7	1.9
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

of pigeonpea of 109.3 and 122.7 cm was recorded with July 1st sowing date (M_1) and was followed by July 20th (M_2) (117.1 and 108.7 cm) and minimum plant height was recorded at August 10th (M_3) (98.4 and 109.0 cm) sowing date during 2018 and 2019 respectively. However, it was at par with July 20th sowing during 2018. Increase in plant height with July 1st sowing date might have represented better weather conditions like prolonged photoperiod, optimum temperatures and sufficient amount of moisture levels at vegetative growth resulting in maximum plant height. These results were in line with those of Singh and Kumar (2014) and Lalitha *et al.* (2018).

Among the integrated nutrient management treatments *i.e.,* 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) had resulted in maximum plant height of 34.7 and 37.3 cm and was at par with application of 100% RDF alone (S_3) with 33.3 and 35.5 cm, during 2018 and 2019. Application of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_3) (32.0 and 33.6 cm) and S_1 *i.e.,* 75% RDF (31.0 cm and 32.2 cm) showed the plant height which was significantly at par.

At 60 DAS, S_4 *i.e.,* 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} registered significantly taller plants (95.1 and 101.8 cm). The plant height obtained with application of 100% RDF (S_3) (88.6 and 97.7 cm) was at par with supplication of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 86.0 and 94.8 cm in 2018 and 2019, respectively. Lower plant height was observed with S_1 (75% RDF) (83.9 and 92.0 cm) during both the years of field study.

With the growth advancement at 90 DAS, administration of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) produced significantly taller plants (107.4 and 124.2 cm) and was at par with 100% RDF (S_3) with 104.7 and 118.1 cm. Distinctly, allocation of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) produced at par plant height (100.4 and 114.0 cm) and was at par with 75% RDF (S_1) with plant height of 98.2 and 108.9 cm during both the years.

A significant effect on the increase on the plant height with the application of NPK may be attributed to nitrogen which is an essential constituent of plant tissue that promotes rapid cell division and its enlargement, which together with the adequate quantity of phosphorus and potassium helps in the rapid cell division and better development of the cell size. Further, the beneficial effect of FYM enriched with microbial consortia may be attributed to the fact that it supplied available plant nutrients and had solubilising effect on fixed forms of nutrients thus making the nutrients available for increased intermodal length thus improving plant height. These results are in conformity with Ade *et al.* (2018).

Interaction effect of plant height of pigeonpea crop as influenced by dates of sowing and integrated nutrient management was found to be non significant in all crop growth stages.

Leaf area plant^{-1} (cm^2)

Perusal of data on leaf area plant^{-1} of pigeonpea at different growth stages as influenced by dates of sowing and different integrated nutrient management were presented in Table 3 during both the years of study.

From the pooled mean (Table 3) of two years it is observed that, in case of sowing dates M_1 (July 1st) sown pigeonpea brought out the maximum leaf area per plant *i.e.,* 99.5, 760.0 and 1031 cm^2 at 30, 60 and 90 DAS of plant growth which was significantly higher compared to other treatments. Sowing on 20th July produced significantly higher leaf area (92.6 cm^2) over 10th August (85.7 cm) sowing at 30 DAS, however, with the advancement of crop growth *i.e.,* at 60 DAS and 90 DAS, 20th July (M_2) sowing (676.0 and 890.0 cm^2) was at par with 10th August (M_3) sowing (655.2 and 880.4 cm^2). Pooled data among the INM treatments recorded that application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) showed significantly higher leaf area at 30 (98.1 cm^2), 60 (767.3 cm^2) and at 90 DAS (1032.4 cm^2) over other treatments. The leaf area (93.8 cm^2) obtained with application of 100% RDF alone (S_3) was at par with leaf area (91.0 cm^2) accrued with 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2). At later stages at 60 and 90 DAS, application of 100% RDF (S_3) showed higher leaf area (719.1 and 968.1 cm^2), that was distinctly followed by S_2 (75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1}) with leaf area of 623.9 and 833.2 cm^2 plant^{-1} was obtained with application of 75% RDF alone (S_1) at 60 DAS and 90 DAS.

Table 3. Effect of dates of sowing and INM on leaf area per plant (cm^2) of super early pigeonpea

Treatments	30 DAS			60 DAS			90 DAS		
	2018	2019	Pooled mean	2018	2019	Pooled mean	2018	2019	Pooled mean
Main treatments (Dates of Sowing)									
M_1 - 1st July	93.2	105.8	99.5	692.4	827.6	760.0	980.0	1082.9	1031.5
M_2 - 20th July	87.6	97.5	92.6	632.6	719.5	676.0	820.4	960.7	890.6
M_3 - 10th August	80.4	91.0	85.7	617.3	693.1	655.2	813.5	947.3	880.4
SE m (±)	1.1	2.5	1.2	14.8	15.6	6.1	30.2	22.0	25.4
CD (P=0.05%)	4.5	9.9	4.7	58.0	61.3	23.8	118.7	86.4	99.9
Sub treatments (INM)									
S_1 - 75 % RDF	82.6	92.4	87.5	577.4	670.4	623.9	735.0	931.5	833.2
S_2 - 75 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	85.6	96.4	91.0	620.1	736.1	678.1	824.1	981.6	902.9
S_3 - 100 % RDF	87.8	99.7	93.8	669.7	768.4	719.1	921.3	1014.9	968.1
S_4 - 100 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	92.3	104.0	98.1	722.6	812.1	767.3	1004.9	1059.9	1032.4
SE m (±)	1.8	2.1	1.0	11.0	22.0	9.7	21.9	31.8	15.9
CD (P=0.05%)	6.3	7.2	3.5	38.1	76.1	33.7	75.7	NS	55.0
Interaction effect									
Main at same level of sub									
SE m (±)	4.0	4.6	2.7	23.7	25.4	15.1	32.6	36.4	21.0
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub at same level of Main									
SE m (±)	3.3	4.2	2.3	22.5	24.0	12.9	36.8	34.2	27.8
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

The scrutiny of the data on leaf area per plant of pigeonpea at 30 DAS was significantly influenced by main plots, *i.e.,* sowing dates during 2018 and 2019, the pigeonpea sown on July 1st had produced significantly more leaf area plant^{-1} (93.2 and 105.8 cm^2) and it was at par with leaf area plant^{-1} obtained with July 20th sowing (M_2). With advancement of crop growth stage at 60 DAS and 90 DAS also, leaf area plant^{-1} recorded in early sowing (July 1st) was significantly higher during 2018 (692.4 and 980.0 cm^2 plant^{-1}) and 2019 (827.6 and 1082.9 cm^2 plant^{-1}). Sowing on 20th July produced leaf area of 632.6, 820.4 cm^2 plant^{-1} during 2018 and 719.5, 960.7 cm^2 plant^{-1} during 60 DAS and 90 DAS respectively which was at par with 10th August sowing (617.3, 813.5 cm^2 plant^{-1} during 2018 and 693.1, 947.3 cm^2 plant^{-1} during 2019 at 60 and 90 DAS respectively). The increase in leaf area could be attributed to significant increase in leaf expansion, high rate of cell division and cell enlargement, rapid vegetative growth due to favourable weather conditions like optimum temperature, rainfall and light *etc*., during crop growing period. These are in line with the results of Kumar *et al.* (2018) and Sharanappa *et al.* (2018).

Among the integrated nutrient treatments at 30 DAS, application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) had produced more leaf spread (92.3 and 104.0 cm^2) and it was on par with 100% RDF (S_3) (87.8 and 99.7 cm^2) during 2018 and 2019. The leaf area obtained with application of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) was at par with the 75% RDF alone during the both the years.

Whereas, 60 DAS, application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) expressed significantly higher leaf area plant^{-1} of 722.6 and 812.1 cm^2 during both the years but was at par with application of 100% RDF (S_3) during 2019. Application of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 620.1 and 736.1 cm^2 leaf area in the both the years was significantly higher leaf area over 75% RDF alone (S_1) during 2018 but found at par in 2019.

At later stages *i.e.,* during flowering and grain filling (90 DAS), higher leaf area plant^{-1} (1004.9 and 1059.9 cm^2) was attained with the 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) which was significantly higher over other treatments. Other treatments also showed distinct variation with higher leaf area (921.3, 1014.9 cm^2) with 100% RDF (S_3), followed by 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with leaf area of 824.1 and 981.6 cm^2 plant^{-1} during both the years. Notably lower leaf area (735.0, 931.5 cm^2 plant^{-1}) was observed with application of 75% RDF alone (S_1) during both the years. Application of recommended dose of NPK results in proper leaf expansion, increases leaf surface area and number of leaves and results in better efficiency of chlorophyll during photosynthesis and this overall improvement gets translocated into better growth of the plant resulting in increased leaf area index. Besides application of FYM enriched microbial consortia, apart from improving soil physico-chemical and biological properties of soil releases adequate quantities of nitrogen and phosphorus to boost up the growth of the crop thereby increasing leaf area. These findings are in conformity with Ade *et al.* (2018).

Interaction of leaf area index of pigeon crop was found non significantly influenced by different dates of sowing (main treatments) and various integrated nutrient management (sub treatments).

Dry matter production (g m^{-2})

Dry matter accumulation is another important character to express the growth and metabolic efficiency of the plant, which ultimately influence the yield. Crop performance and final crop yield depends on total dry matter accumulation at different crop growth stages. To visualize the influence of different treatments, the data pertaining to dry matter accumulation at different growth stages *i.e.,* 30, 60 and 90 DAS were analysed statistically and is presented in Table 4.

The pooled results from 2018 and 2019 showed that, the significantly highest dry matter accumulation at 30, 60 and 90 DAS respectively (47.5, 268.7 and 441.1 g m^{-2}) was the result of early sowing in July 1st due to higher metabolic activity of the plants and solar energy harvesting efficiency of plants in the optimum sowing time coupled with favourable climate conditions especially temperature, rainfall and solar radiation which produced higher dry matter. The variation between dry matter accumulation at 20th July (M_2) and 10th August (M_3) was at 30 DAS not different significantly by accumulating 42.9 and 40.8 g m^{-2}, As the crop advances to flowering and maturity stages *i.e.,* 60 and 90 DAS, the dry matter accumulated at 60 and 90 DAS for July 20th (M_2) sowing was significantly higher over the August 10th (M_3) sowing. In the sub treatment, nitrogen supplied through the inorganic and organic sources like application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} had significantly recorded higher accumulation of dry matter at 30 (49.4 g m^{-2}), 60 (286.3 g m^{-2}) and 90 DAS (457.6 g m^{-2}). Whereas at 30 DAS, there is no significant difference in accumulation of dry matter with application of 100% RDF alone (S_3) and 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4). As the crop growth progress to 60 and 90 days, notable variation was observed in the dry matter accumulation between supplication of 100% RDF (S_3) and 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4). The least dry matter accretion was realized by the administering 75% RDF alone (S_1) at 30, 60 and 90 DAS of the pooled results shown in the Table 4.

During both the years of field study *i.e.,* 2018 and 2019 at 30 days after sowing, pigeonpea crop sown on July 1st (M_1) recorded dry matter accumulation (45.6 and 49.4 g m^{-2}) and was at par with 20th July sowing (42.3 g m^{-2}) in 2018 and significantly higher in 2019 with 43.6 g m^{-2}. The dry matter accumulation in July 20th and August 10th were found significantly indistinct at 30 DAS. At 60 DAS, early sowing of pigeonpea on July 1st (M_1) (246.8 and 290.6 g m^{-2}) was recorded significantly higher dry matter accumulated during 2018 and 2019 compared to late sowing on August 10th sowing (195.6 and 236.4 g m^{-2}). The pigeonpea sown on July 20th (229.5 and 270.9 g m^{-2}) was on par with early sown pigeonpea *i.e.,* July 1st in the first and second year of experiment. Likewise, 90 DAS of pigeonpea also reported almost similar results *i.e.,* July 1st (M_1) sown pigeonpea has recorded highest dry matter accumulation with 402.3 and 480.0 g m^{-2} in 2018 and 2019. This was at par with July 20th (M_2) in

Table 4. Effect of dates of sowing and INM on dry matter production (g m-2) of super early pigeonpea

Treatments	30 DAS			60 DAS			90 DAS		
	2018	2019	Pooled mean	2018	2019	Pooled mean	2018	2019	Pooled mean
Main treatments (Dates of Sowing)									
M_1 - 1st July	45.6	49.4	47.5	246.8	290.6	268.7	402.3	480.0	441.1
M_2 - 20th July	42.3	43.6	42.9	229.5	270.9	250.2	368.7	415.7	392.2
M_3 - 10th August	40.4	41.1	40.8	195.6	236.4	216.0	318.7	367.1	342.9
SE m (±)	0.9	1.0	0.7	5.9	8.8	3.6	11.2	12.9	8.9
CD (P=0.05%)	3.6	3.8	2.8	23.1	34.5	14.0	43.9	50.8	34.8
Sub treatments (INM)									
S_1 - 75 % RDF	40.5	39.3	39.9	177.8	236.3	207.0	303.4	349.6	326.5
S_2 - 75 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	41.0	42.6	41.8	201.8	255.8	228.8	330.6	403.6	367.1
S_3 - 100 % RDF	43.5	44.2	43.9	247.4	268.1	257.8	388.7	445.5	417.1
S_4 - 100 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	46.3	52.7	49.4	269.0	303.6	286.3	430.3	485.0	457.6
SE m (±)	1.0	1.1	0.7	4.7	9.5	6.9	5.2	10.8	6.9
CD (P=0.05%)	3.5	3.7	2.4	16.1	33.0	23.8	17.9	37.2	23.9
Interaction effect									
Main at same level of sub									
SE m (±)	3.3	1.8	2.3	8.9	11.6	8.3	17.5	22.6	14.0
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub at same level of Main									
SE m (±)	2.7	1.7	1.9	8.6	11.9	7.1	16.8	20.9	13.4
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

2018 and significantly higher over July 20th (M_2) in 2019. The lowest dry matter accumulation was realized by late sowing of pigeonpea on August 10th (M_3) with accumulation of 318.7 and 367.1 g m^{-2} dry matter during 2018 and 2019 respectively. Among all the dates of sowing, July 1st (M_1) was shown to be superior to other sowing dates in terms of dry matter accumulation which might be due to congenial weather condition like optimum amount and uniform distribution of rainfall and favorable temperature prevailed during vegetative period of pigeopea crop which helped in improvement of dry matter production. These results were in conformity with Patel *et al.* (2000) and Rajesh *et al*. (2020).

The pigeonpea crop fertilized with 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) at 30 DAS had produced dry matter accumulation (46.3 and 52.7 g m^{-2}) which was at par with 100% RDF (S_3) alone in 2018 and significantly higher in 2019. The application of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 41.0 and 42.6 g m^{-2} in 2018 and 2019 was found at par with 75% RDF alone (S_1) with 40.5 g m^{-2} in 2018 and significantly higher over 39.3 g m^{-2} dry matter accumulated in the year 2019. At 60 DAS also, application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) had significantly recorded higher dry matter accumulation (269.0 and 303.6 g m^{-2}) followed by application of 100% RDF alone (S_3) (247.4 and 268.1 g m^{-2}). The INM practice with 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 201.8 and 255.8 g m^{-2} recorded significant results over the 75% RDF (S_1) during 2018 and 2019, respectively.

The maximum dry matter production of pigeonpea at 90 DAS was recorded with 100% RDF

+ FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) (430.3 and 485.0 g m^{-2}) which was significantly higher over the dry matter registered with S_3 *i.e.,* 100 % RDF (388.7 and 445.5 g m^{-2}) and 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 330.6 and 403.6 g m^{-2}. The lowest dry matter accumulation was realized with S_1 *i.e.*, 75% RDF (303.4 and 349.3 g m^{-2}) only during 2018 and 2019, respectively. The increase in periodic dry matter accumulation with application of integrated fertilizer management may be attributed to increase in plant height and leaf area index resulting in better light interception by crop which accumulated more photosynthates and thus produced more dry matter. Further, FYM enriched with microbial consortia brought nutrients to available form in gradual process and improved the soil physical characters, which might have increased the availability of nutrients. These results are in line with those of Tilak *et al.* (2006).

Interaction effect between sowing dates and integrated nutrient management was non significant in respective to dry mater production at all the growth stages of pigeonpea crop.

YIELD

Seed yield (kg ha^{-1})

Seed yield of pigeonpea as influenced by dates of sowing and different INM are presented in Table 5. On the basis of pooled analysis, it was observed that the seed yield ranged between 559 to 759 kg ha^{-1} among the different treatments. Significantly the higher seed yield of pigeonpea (759 kg ha^{-1}) was recorded with early sowing on July 1st treatment followed by the July 20th sowing with 626 kg ha^{-1}. Significantly lower seed yield was noticed as pigeonpea crop sown on August 10th (M_3) with 576 kg ha^{-1} seed yield. Similarly, the combined application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1}

Table 5. Effect of dates of sowing and INM on yield of super early pigeonpea

Treatments	Seed Yield (kg ha^{-1})			Stover Yield (kg ha^{-1})			Harvest Index (%)		
	2018	2019	Pooled mean	2018	2019	Pooled mean	2018	2019	Pooled mean
Main treatments (Dates of Sowing)									
M_1 - 1st July	739	779	759	3402.5	3527.4	3464.9	17.8	18.0	17.9
M_2 - 20th July	606	646	626	3146.4	3245.4	3195.9	16.1	16.6	16.3
M_3 - 10th August	545	573	559	3052.3	3121.6	3087.0	15.1	15.5	15.3
SE m (±)	20.0	14.8	17.2	56.8	77.5	62.2	0.4	0.4	0.4
CD (P=0.05%)	78.5	58.0	67.7	223.1	304.1	244.2	1.7	1.6	1.6
Sub treatments (INM)									
S_1 - 75 % RDF	554	594	574	3043.1	3113.4	3078.2	15.4	16.0	15.7
S_2 - 75 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	598	632	615	3138.7	3269.4	3204.0	15.9	16.1	16.0
S_3 - 100 % RDF	645	678	662	3251.5	3356.0	3303.8	16.5	16.8	16.7
S_4 - 100 % RDF + FYM enriched with microbial consortia (1 t ha^{-1})	724	758	741	3368.3	3453.7	3411.0	17.5	17.9	17.7
SE m (±)	14.4	11.7	12.2	36.2	42.8	25.5	0.3	0.3	0.3
CD (P=0.05%)	49.7	40.6	42.2	125.3	148.2	88.4	1.1	1.1	0.9
Interaction effect									
Main at same level of sub									
SE m (±)	27.0	28.0	26.4	83.2	113.8	79.7	0.7	0.8	0.7
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub at same level of Main									
SE m (±)	27.3	25.1	25.5	81.6	111.5	82.7	0.7	0.7	0.6
CD (P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

(S_4) was identified as best INM practice to yield 741 kg ha^{-1} seed. The next best treatment followed significantly with supplication of 100% RDF alone (S_3) with 662 kg ha^{-1} and application of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 615 kg ha^{-1}. Significantly lower seed yield was noticed with administering of 75% RDF (S_1) with 574 kg ha^{-1}.

Seed yield was significantly influenced by dates of sowing during 2018 and 2019. The data on seed yield revealed that, maximum seed yield was (739 and 779 kg ha^{-1}) produced when pigeonpea was sown on July 1st (M_1) and was significantly higher over July 20th (606 and 646 kg ha^{-1}) and August 10th (545 and 573 kg ha^{-1}) sowing dates. The higher seed yield with July 30th sowing was probably due to good seed set favoured by warm weather prevailed during at maturity. Similar results were reported by Chih-Li Yu *et al.* (2014) and Patil *et al.* (2018).

The seed yield of pigeonpea was higher with application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) with 724 and 758 kg ha^{-1} in 2018 and 2019 years respectively. These findings were significantly superior over the provision of 100% RDF alone (S_3) with 645 and 678 kg ha^{-1} and followed by 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) (598 and 632 kg ha^{-1}). The minimum seed yield was obtained with the application of 75% RDF alone (S_1) with 554 and 594 kg ha^{-1} during 2018 and 2019 respectively. Significant increase in seed yield of pigeonpea with fertilizers coupled with organic manures might have supplied nutrients improving crop growth, nutrient uptake and yield attributes. Similar results were reported by Ahmad *et al.* (2017) and Ade *et al.* (2018).

The synergy effect of sowing dates and integrated nutrient management were not statistically significant during both the years of experimentation.

Stover yield (kg ha^{-1})

Stover yield of pigeonpea as influenced by dates of sowing and different INM are presented in Table 5. The pooled analysis of the two years data revealed that, the significantly higher stover yield of pigeonpea was recorded with the timely sowing of pigeonpea *i.e.,* on July 1st (M_1) (3465 kg ha^{-1}) followed by the July 20th (M_2) with 3196 kg ha^{-1} and August 10th (M_3) with 3087 kg ha^{-1} stover yield. Similarly, the combination of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) was identified as best INM practice to produce 3411 kg ha^{-1} stover yield. The next best INM practice was application of 100% RDF (S_3) with 3304 kg ha^{-1} and followed by administering of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 3204 kg ha^{-1}. Significantly lower stover yield was noticed under in the S_1 (75% RDF) treatment with 3078 kg ha^{-1}.

Stover yield was significantly influenced by dates of sowing during 2018 and 2019. The data on stover yield revealed that, maximum stover yield was (3402 and 3527 kg ha^{-1}) produced when pigeonpea was sown on July 1st (M_1) and was significantly higher over July 20th stover yield (3146 kg ha^{-1}) in 2018 and at par in 2019 (3245 kg ha^{-1}). The lower stover yield was administered with August 10th sowing with 3052 and 3122 kg ha^{-1} during 2018 and 2019 years. Stover yield of crop is the outcome of plant through growth attributes like plant height, dry matter accumulation and partitioning of dry matter at grain filling stage. Sowing of pigeonpea on July 1st resulted maximum stover yield due to optimum utilization of solar radiation, temperature, higher assimilates production and its conversion to starch results in higher straw yield. These finding are similar to those reported by Egbe *et al.* (2013) and Malik and Yadav (2014).

The stover yield of pigeonpea was higher with application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) with 3368 and 3454 kg ha^{-1} in first and second years and was on par with supplication of 100% RDF alone (S_3) in 2018 with 3251 kg ha^{-1} and significantly differed in 2019 with 3356 kg ha^{-1} stover yield. The application of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) recorded 3139 and 3269 kg ha^{-1} of stover yield in 2018 and 2019. This was on par with stover yield recorded by supplication of 75% RDF alone (S_1) in 2018 and significantly superior in 2019. Significant increase in stover yield of pigeonpea with fertilizers coupled with organic manures might have supplied nutrients for good crop growth, nutrient uptake and yield attributes. Similar results were reported by Ahmad *et al.* (2017).

The interaction effect of sowing dates and integrated nutrient management were not statistically significant during both the years of experimentation.

Harvest index (%)

The data on harvest index (HI) as influenced by main and sub treatments is presented in Table 5. Harvest index of pigeonpea was influenced by sowing dates in the main treatments and the expressed in pooled results of the 2018 and 2019 revealed that, significantly highest harvest index was recorded by the July 1st (M1) sown pigeonpea (17.9%) and it was on par with July 20th sowing (16.3%) and followed significantly with August 10th date of sowing (15.3%). Similarly in the subplot INM treatments 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) was identified as best INM practice to attain highest harvest index with 17.7% followed by fertilization with 100% RDF (S_3) with 16.7% and application of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) with 16.0%. Significantly lower harvest index was noticed under in the S_1 (75% RDF) treatment with 15.7%.

Sowing of pigeonpea crop on July 1st resulted significantly highest harvest index (17.8 and 18.0%) and it was on par with July 20th in the year 2019 with 16.6%. Minimum harvest index was obtained with August 10th sown (M_3) with 15.1 and 15.5 during both the years. Optimum utilization of solar radiation, temperature, higher assimilates production and its conversion to starch results in higher biomass, seed yield leading to higher harvest index. These observations corroborated with those made by Kumar *et al.* (2008).

Integrated nutrient management treatments during the both the years, application of 100% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_4) was recorded highest harvest index (17.5 and 17.9% respectively) fallowed on par by application of 100% RDF (S_3) with 16.5 and 16.8%. The administration of 75% RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} (S_2) recorded 15.9 and 16.1% of harvest index was significantly on par with application of 75% RDF only (S_1) (15.4 and 16.0%) in the first and second year of study. Balanced nutrition through inorganic fertilizers coupled with organic manures had supplied nutrients for higher biomass, seed yields, partitioning of dry matter between grain and other plant parts leading to higher harvest index, similar results confirmed by Ade *et al.* (2018).

The interaction effects of harvest index of pigeonpea with sowing dates and integrated nutrient management were non significant during both the years of experiment.

CONCLUSION

Based on the research results, it is concluded that the sowing super early pigeonpea in the first fort of July and with 100 RDF + FYM enriched with microbial consortia @ 1 tonne ha^{-1} resulted in relatively higher final plant population, plant height, leaf area per plant and dry matter accumulation and finally responsible to attain maximum seed yield, stover yield and harvest index of super early pigeonpea. It passed the way for super early pigeonpea based double cropping system in semi arid regions of Telangana.

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