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Bio-inoculated Nutrient Management Influence on Soil Nutrient Availability Pattern and Growth of Hybrid Pigeonpea (ICPH 2740) under Establishment Methods and Crop Geometry

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ABSTRACT

Background: A two-year field study was conducted at the ICRISAT research farm during the rainy seasons of 2021 and 2022 to investigate the impact of crop geometry, crop establishment method and sustainable nutrient management practices on nutrient availability pattern and growth of hybrid pigeon pea.

Methods: The experiment followed a split-split plot design. The collected data was analysed using radar graph and heat maps for nutrient availability and dry matter respectively.

Result: Data revealing that transplanted plots registered higher nutrient availability and proportionate root and total dry matter production at various growth stages. Among plant geometry the root and total dry matter production was higher with 100×100 cm. when considering planting methods, transplanting with a square system of 100×100 cm, combined with an integrated nutrient management approach consisting of 150% (or) 100% soil test based NPK, vermicompost at a rate of 5 t ha^{-1}, phosphate-solubilizing bacteria (PSB) and seed treatment with *Rhizobium*, resulted in average of 31.5% higher dry matter production over alone inorganic nutrient management practices. Thus, a square geometry of 100×100 cm, along with sustainable integrated nutrient management (100% soil test based NPK, vermicompost at a rate of 5 t ha^{-1}, PSB and seed treatment with *Rhizobium*), resulted in higher nutrient availability and dry matter production. These findings highlight the importance of careful selection of planting methods, crop geometry and nutrient management practices for maximizing the nutrient mining for production of high dry matter production of hybrid pigeonpea.

Key words: Dry matter production, Hybrid pigeonpea, Phosphorus solubilizing bacteria, *Rhizobium*, Soil nutrient availability.

INTRODUCTION

Now-a-days, farmers face challenges in sowing pigeonpea within the ideal planting window due to irregularities in monsoon patterns (Varatharajan *et al*., 2019a; Kumar *et al*., 2021). Moreover, most of the available varieties and hybrids of pigeonpea are photo-sensitive, meaning they enter the reproductive stage when they receive the optimum day length, regardless of the actual sowing time (Varatharajan *et al*., 2019b). As a result, source development in these plants is constrained (Tigga and Singh, 2019). To address the issue of source-sink imbalances and ensure proper plant development, the concept of transplanting emerged as an alternative to conventional dibbling methods. In this study, the modern transplanting technique was compared with the traditional dibbling method in the main plot treatment. However, it was observed that conventional crop geometry like 150 × 30 cm resulted in significant interplant competition, leading to poor plant expression (Pradeep *et al*., 2018). Therefore, to avoid these challenges, the plant geometry was considered as a sub-factor in this study.

Higher wider plant geometry especially the hybrid has higher nutrient requirement under clay soils. In order to fulfil demanded nutrient in sustainable manner by integrated approach. Pigeonpea is a deep-rooted crop which can able to extract nutrients from deeper layer of soil at later stages of crop (Singh *et al*., 2020; 2022a). The initial nutrient requirement especially nitrogen through biological nitrogen fixation and phosphorus mostly in fixed (or) complex form which may not be available to plant. The unavailable phosphorus makes into available by the activity of phosphorus solubilizing bacteria. With respect to phosphorus at later stages the fixed phosphorus can be

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converted to available form by releasing the piscidic acid by roots (Ishikawa *et al*., 2002). In order to understand the activity of *Rhizobium* and phosphorus solubilizing bacteria (PSB), nutrient availability pattern of soil was examined at various stages of crop phenology. The objective of the present study was to find out the effect of nutrient management practice on nutrient release pattern and proportionate root growth, total dry matter production under planting methods and plant geometry.

MATERIALS AND METHODS

Experimental site

A field study was conducted at the "International Crops Research Institute for Semi-Arid Tropics" (ICRISAT), Patancheru, Hyderabad, during rainy season (*kharif) of* 2021 and 2022. The experimental periods experienced a rainfall of 998.4 mm in 55 rainy days during 2021 and 1000 mm in 53 rainy days during 2022. The experimental plot was characterized by clay soil with a pH of 8.1, an electrical conductivity (EC) of 1.94 dSm^{-1} and organic carbon content of 0.42%. The soil analysis prior to the commencement of the trial revealed that the available nitrogen (N), phosphorus (P) and potassium (K) were 231.1 kg N ha^{-1}, 29.8 kg P_2O_5 ha^{-1}, 350.5 kg K_2O ha^{-1}, respectively.

Treatment and experimental design

The field study was conducted using a split-split plot design. The main plot treatments consisted of two planting methods of pigeonpea *viz*., M_1: Dibbling, M_2: Transplanting. The sub-plots treatments were crop geometry *viz*., S_1: 100 cm × 100 cm (10,000 plants ha^{-1}), S_2: 120 cm × 120 cm (6,944 plants ha^{-1}), S_3: 150 cm × 60 cm (11,111 plants ha^{-1}). The sub-sub plots treatments involve five nutrient management practice *viz*., N_1: Control, N_2: 100% soil test-based (STB) NPK (25:37.5:8.5 kg ha^{-1}), N_3: 100% STB NPK + vermicompost + Phosphate-solubilizing bacteria (PSB) + Seed treatment (ST) with *Rhizobium*, N_4: 150% STB NPK, N_5: 150% STB NPK + vermicompost + PSB + ST with *Rhizobium.* Dibbling was performed on the same day of transplantation using seedlings that were 23 days and 25 days old during the *kharif* season of 2021 and 2022, respectively. The sowing was done on 20th June and 23th June during *kharif* 2021and 2022 respectively. The hybrid used in this investigation was ICPH 2740 which was released in 2015 in Telangana on name of mannemkonda kandi.

Data collection

The weight of dry matter is an index of productive capacity of the plant. The plants harvested from each plot boarder rows for estimating dry matter production. The roots were clipped off from each selected plant, transferred to properly labeled cloth bags separately and then partially dried in the shade. Later on, they were subjected to oven drying at 65±2°C until constant weights were recorded and expressed as total dry matter production (kg ha^{-1}) and root dry weight (kg ha^{-1}) at 45, 90, 135 DAS and harvest (Rana *et al*., 2014).

Available nitrogen (kg ha^{-1})

Available nitrogen in soil was determined by 2 M KCl extraction with continuous flow analyser at 560 nm method as described by Keeney and Nelson (1983).

Available phosphorus (kg ha^{-1})

Available phosphorus was extracted from soil by Olsen's reagent (0.5 N $NaHCO_3$, pH 8.5). The colour development (blue colour) was done by ascorbic acid method given by Watanabe and Olsen (1965) and the intensity of the blue colour was measured at 8800 nm wavelength by using continuous flow analyser.

Statistical analysis

The heat map was generated using GraphPad Prism Version 9.5.1(733) to visualize the root dry matter and total dry matter production at different stages of crop growth under different agronomic practices during the *kharif* season of 2021 and 2022. To ensure proper comparison, the data for root and dry matter production were normalized column-wise. The normalization process involved setting the minimum value as zero per cent and the maximum value as one hundred percent. This allowed for a standardized representation of the data on the heat map.

RESULTS AND DISCUSSION

Soil available nitrogen and phosphorus

For easy and better understanding of soil available nitrogen and phosphorus at different stages of crop depicted in the form of radar grape in Fig 1 and 2, respectively during *kharif* 2021. In this radar graph, the treatments are distributed around the circle, the nutrient availability of pattern at different stages represented with different colour, from centre to periphery there is scale which represents increasing order of nutrient availability from centre to outside of circle. The outer circle which represented with green colour represents the higher and inner circle with red colour denotes lower nutrient availability, respectively.

From this grape, we knew that the soil nitrogen and phosphorus availability was increased from 45 to 90 DAS, but, there onwards gradually increase in trend was shown in all the treatment combinations. Higher soil nutrient availability was recorded in combination of integrated nutrient approach *i.e.* 100% soil test based NPK + vermicompost @ 5 t ha^{-1} + vermicompost enriched with PSB + seed treatment with *Rhizobium* which was on par with 150% soil test based NPK + vermicompost @ 5 t ha^{-1} + vermicompost enriched with PSB + seed treatment with *Rhizobium.* Compared to control and inorganic plots the average nutrient (nitrogen and phosphorus) availability was increased 28.1 and 22.2%; 11.6 and 14.8% higher with integrated nutrient management practices during 90 DAS (where highest nutrient availability was registered). With respect to the planting methods at 45 and 90 DAS, higher nutrient availability was recorded with transplanting over dibbling in both the years. Whereas, in plant geometry the nutrient availability was found non-significant at 45 and 90 DAS. Due to addition of vermicompost and bio-inoculants, the activity of soil micro-fauna was improved so nutrient availability increased by mineralization process (Kumar *et al*., 2014, 2022), in this way the integrated approach treatments recorded higher nutrient availability compared to the sole inorganic fertilizer application. These results are in tune with Choudhary *et al*. (2013) and Yadav *et al*. (2015).

Dry matter production

The data on root and total dry matter production at 45, 90, 135 DAS and harvest were represented in the form of heat maps (Fig 3, 4) during *kharif* 2021 and 2022, respectively. Analysis of the heat map reveals that the combination of transplanting with wider spacing (100×100 cm plant geometry) in conjunction with the application of 150% soil test based NPK + vermicompost @ 5 t ha^{-1} + vermicompost enriched with PSB + seed treatment with *Rhizobium*, resulted in higher root dry matter and total dry matter production at all the stages as depicted by the intensive red colour. However, when considering, root dry matter plant^{-1}, it was observed that transplanting with wider spacing (120×120 cm plant geometry) in combination with 150% soil test based NPK + vermicompost @ 5 t ha^{-1} + vermicompost enriched with PSB + seed treatment with *Rhizobium,* resulted in higher values compared to the wider square geometry (100×100 cm) as mentioned earlier.

Dry matter production was not proportionately increased under wider plant geometry despite same level of soil nutrient availability. This might be because of higher nutrient availability due to lack of optimum plant population in wider plant geometry (Kumar *et al*., 2020, 2021). Whereas, with planting methods slow initial growth and lower root development at later stages in case of dibbling over transplanting led to low nutrient uptake and use-efficiency (Rajpoot *et al*., 2016, 2021).

At harvest, total dry-matter production was 26.1 and 30.8% higher in case of transplanting over dibbling during *kharif* 2021 and 2022, respectively. In case of transplanting, due to vigorous growth during initial stages led to effective uptake and utilization in initial period as a result of nutrient availability. Not only by increased availability, but also required optimum plant population to utilize the available nutrients in case of 100×100

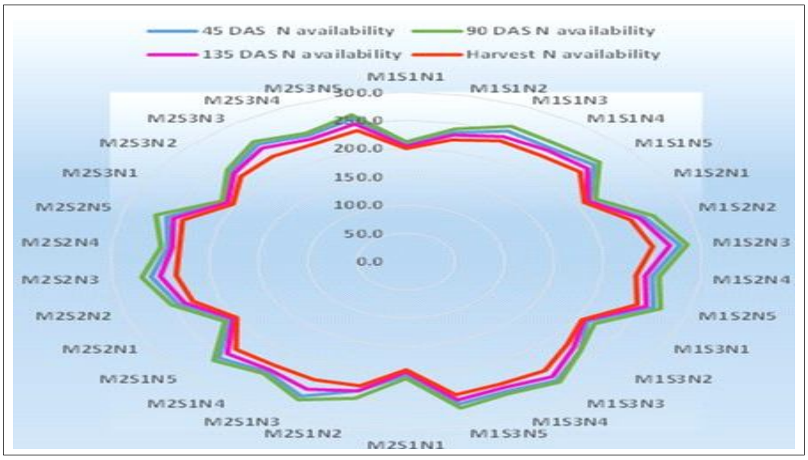

Fig 1: Soil available nitrogen pattern of hybrid pigeonpea under agronomic practices during *kharif* 2021.

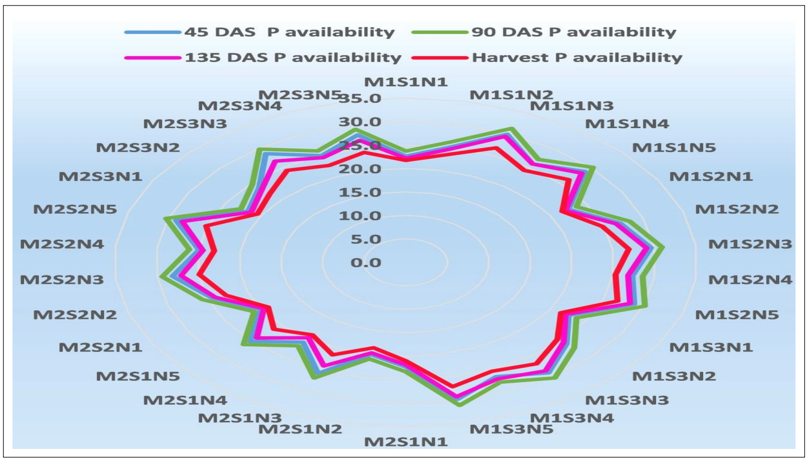

Fig 2: Soil available phosphorus pattern of hybrid pigeonpea under agronomic practices during *kharif* 2021.

cm plant geometry registering 18.6 and 16.9% higher total dry matter production (kg ha^{-1}) over 120×120 cm plant geometry during *kharif* 2021 and 2022 despite the per plant dry matter was higher with later plant geometry. When considering all the three factors, transplanting with (100×100 cm plant geometry) in conjunction with 100% soil test based NPK + vermicompost @ 5 t ha^{-1} + vermicompost enriched with PSB + seed treatment with *Rhizobium* recorded 28.7 and 23.7% higher than sole 100% soil test based NPK. Same treatment combination in comparison to control obtained 56.7 and 57.2% higher during *kharif* 2021 and 2022, respectively at harvest.

Effective utilization of available nutrients is known to increase nutrient-use efficiency, thereby, dry matter production (Rajpoot *et al*., 2018, 2019). The bio-inoculated integrated nutrient management also plays a crucial role in making nutrients available forms at initial stages of crop

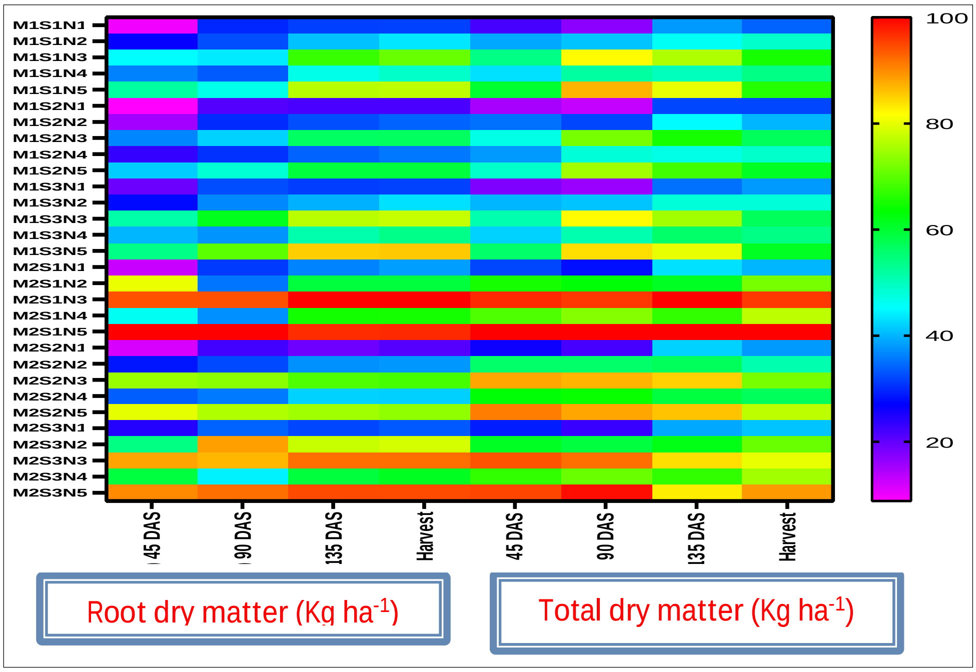

Fig 3: Heat maps showing root and stem dry matter production influenced by agronomic practices during *kharif* 2021.

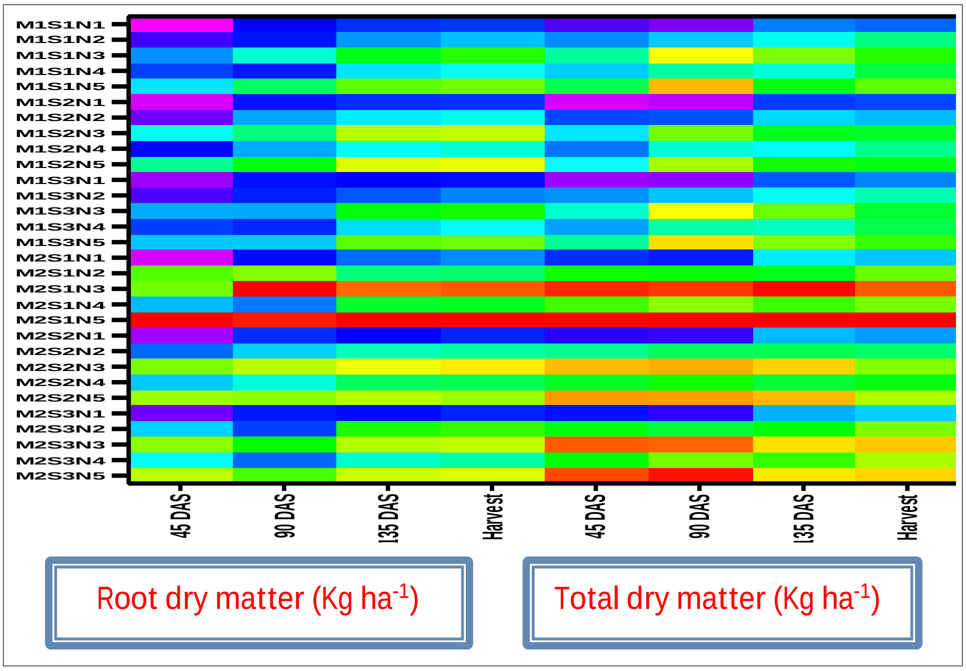

Fig 4: Heat maps showing root and stem dry matter production influenced by agronomic practices during *kharif* 2022.

growth (Suri *et al*., 2006; Choudhary *et al*., 2013; Singh *et al*., 2022b). Additionally, crop geometry provides an opportunity for better nutrient uptake, thereby, optimum plant expression in terms of growth and development was obtained (Rajpoot *et al*., 2018, 2021; Gupta *et al*., 2022). Therefore, the combination of transplanting with square geometry and integrated nutrient management practices can enhance soil nutrient availability and dry matter production by effective use of available nutrients.

CONCLUSION

The hybrid pigeonpea exhibited a highly favourable environment for effective utilisation of available nutrients with maximum root development. This was achieved through the implementation of the transplanting method of establishment along with a square geometry of 100×100 cm. Furthermore, the provision of the required nutrient levels through integrated 100% soil test based NPK + vermicompost 5 t ha^{-1} + vermicompost enriched with PSB + *Rhizobium* seed treatment, contributed to higher total dry matter production pays way for nutrient use efficiency and higher yield in pigeonpea.

Conflict of interest: None.

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