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Effect of different Tillage and Residue Management Practices on Nodules Number of Pigeonpea under Pigeonpea + Maize Inter Cropping Systems in Semi-arid Tropics

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ABSTRACT: Pigeonpea (*Cajanus cajan* L.) plays a pivotal role in sustaining millions of resource-poor farmers across semi-arid regions in Asia and Africa. Amidst the challenges of global climate change, this study investigates the effect of Different Tillage and Residue Management Practices on Nodule Number of Pigeonpea under Pigeonpea + Maize Intercropping Systems in Semi-Arid Tropics. The research was conducted in ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), situated in Patancheru, Hyderabad. The experiment was laid out in split-split design. Treatments consists of 2 tillage practices (minimum tillage (Running rotavator once two months before sowing of the crop + Herbicide use as Pre & Post emergence) and conventional tillage (Ploughed with mould board plough once, cultivated and harrowed twice + 2 HW and 1 weeding), 4 row ratios (pigeonpea + maize (1:2 in Additive series), pigeonpea + maize (1:3 in additive series), sole pigeonpea, sole maize) and 3 residue management practices (biochar - Soil application (biochar of pigeonpea stubbles @ 5 t ha^{-1}) residues maize residues as per available crop; in intercropping, quantity is as per crop proportion) and control (no. biochar and no. residue). The experiment was laid out in a split – split plot design with 3 replications. The five plants from border rows were uprooted carefully by digging around the plant by crowbar and the plants were washed under running tap in sieve and the fresh nodules and dry nodules were counted and expressed in (No. plant^{-1}) at active nodulation stages *i.e.* 30, 45 and 60 days after sowing. Row ratios and residue management practices had a significant influence on number of nodules in pigeonpea under pigeonpea and maize intercropping systems in semi-arid tropics.

Keywords: Pigeonpea, Tillage, Row ratios and Residue management practices.

INTRODUCTION

Pigeonpea (*Cajanus cajan* L.) is grown by millions of resource-poor farmers on marginal lands across the semi-arid regions of Asia and Africa. It is a major contributor to food security in areas facing the early effects of global climate change.

Tillage is one of the important contributors to soil carbon storage in agricultural production systems in form of allowing or restricting the soil carbon mass to oxidation. In the recent past, conservation tillage is gaining economic and environmental significance under changing climatic conditions (Singh *et al*., 2014). Conservation tillage is regarded as a potential mitigation strategy to enhance the sink for atmospheric carbon in agriculture. Tillage practices varying in the intensity and type, alter the distribution of crop residues and organic carbon content in the soil profile. No. tillage (NT) and reduced tillage (RT) are the two common variants of conservation agriculture having promise for soil carbon (C) sequestration (Singh *et al*., 2014). In many, though not in all instances, the amount of soil organic matter increases with the adoption of conservation tillage (Paustian *et al*., 1997) which in turn improves soil health (Lenka *et al*., 2014).

Residue and biochar supplementation could also offer great agricultural benefits such as improvement of crop yield in many field crops and reduce nutrient losses (Liu *et al*., 2016). In the recent past, biochar assumed greater importance because of its vital role in abating climate change, enhancement of soil fertility and sustainable agriculture (Chan *et al*., 2008). However, effects of biochar addition on soil C stability and soil fertility in term of grain yields are not always uniform that may vary under different soil conditions and crop type (Palansooriya *et al*., 2019). Similarly, residues as mulch have the potential to improve crop yields dependent upon climatic conditions, cropping systems and water management practices (Pittelkow *et al*., 2015).

Studying row ratio in agricultural practices is crucial for optimizing crop yield, resource efficiency, and sustainability. Proper spacing between crop rows directly impacts factors such as sunlight exposure, nutrient distribution, and weed competition, influencing overall productivity. Research by Kovács and Németh (2016) highlights the positive correlation between optimal row spacing and maize yield. Moreover, adequate row spacing enhances water management and reduces weed competition, as demonstrated in studies like Abou Khaled *et al*. (2020). Disease and pest management also benefit from improved air circulation, reducing the risk of outbreaks, as discussed by Bock *et al*. (2018). Furthermore, row spacing influences mechanical operations, impacting planting, harvesting, and equipment use, as outlined in Kitchen and McDonald's work (2015).

This study's significance lies in its potential to offer practical solutions to challenges faced by farmers in semi-arid tropics. By elucidating the relationship between tillage, residue management, and nodule formation in intercropping systems, this research can contribute to more resilient, productive, and sustainable agricultural practices that address food security, resource scarcity, and climate change adaptation.

MATERIAL AND METHODS

The research was conducted in ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), situated in Patancheru, Hyderabad, Telangana, at an altitude of 461 m above mean sea level (MSL) at 17° 15′N latitude and 77° 35′E longitude. The experimental site comes under the Southern Agro-climatic zone of Telangana. The length of the growing period (LGP) varies from 120 to 150 days (Naidu *et al*., 2015).

The experiment was laid out in split-split design. Treatments consists of 2 tillage practices (minimum tillage (Running rotavator once two months before sowing of the crop + Herbicide use as Pre & Post emergence) and conventional tillage (Ploughed with mould board plough once, cultivated and harrowed twice + 2 HW and 1 weeding), 4 row ratios (pigeonpea + maize (1:2 in Additive series), pigeonpea + maize (1:3 in additive series), sole pigeonpea, sole maize) and 3 residue management practices (biochar - Soil application (biochar of pigeonpea stubbles @ 5 t ha^{-1}) residues maize residues as per available crop; in intercropping, quantity is as per crop proportion) and control (no. biochar and no. residue). The experiment was laid out in a split – split plot design with 3 replications.

The five plants from border rows were uprooted carefully by digging around the plant by crowbar and the plants were washed under running tap in sieve and the fresh nodules and dry nodules were counted and expressed in (No. $plant^{-1}$) at active nodulation stages *i.e.* 30, 45 and 60 DAS.

RESULTS AND DISCUSSION

A. Number of fresh nodules per plant

Effect of tillage. Tillage practices had not shown any significant influence on fresh nodules during both the years, but conventional tillage (M_2) produced higher number of fresh nodules of 19.73 and 22.04 cm during 2021 & 2022. Lower number of fresh nodules was noticed with minimum tillage (M_2) (17.69 and 19.51) in both the years at 30 DAS.

Number of fresh nodules increased dramatically as plant age approached to 45 days. Despite this, conventional tillage (M_2) produced more number of fresh nodules of 46.64 and 60.01 than minimum tillage (40.79 and 55.70) in 2021 and 2022.

As crop advanced to 60 days, higher number of fresh nodules was accrued with conventional tillage (M_2) (54.41 and 74.35) while lower number of fresh nodules was by minimum tillage (M_1) (48.59 and 64.52).

Effect of row ratios. Row ratios shown differs significantly in number of fresh nodules wherein higher number of fresh nodules was recorded in sole pigeonpea (R_3) (20.57 and 22.73) compared other treatments i.e. (R_1) pigeonpea + maize (1:2) (18.80 and 20.86) & (R_2) pigeonpea + maize (1:3) (16.76 and 18.75) during 2021 and 2022 respectively at 30 DAS.

At 45 DAS, row ratios differ significantly in terms of in number of fresh nodules, with sole pigeonpea (R_3) producing more in number of fresh nodules (48.27 and 62.87) than other treatments (R_1) pigeonpea + maize (1:2) (43.89 and 58.05) and (R_2) pigeonpea + maize (1:3) (38.98 and 52.65) during 2021 and 2022, respectively.

During 2021 and 2022, row ratios found to be significant in response with number of fresh nodules. Higher amount of number of fresh nodules was recorded in sole pigeonpea (R_3) (56.81 and 75.82). Whereas, lower number of fresh nodules was observed in R_1 i.e. Pigeonpea + maize (1:3) (45.98 and 62.80) at 60 DAS.

Effect of residue management practices. Residue management practices shown significantly difference on number of fresh nodules. Among residue management practices S_1 i.e. biochar (21.53 and 23.67) recorded higher number of fresh nodules and lower number of fresh nodules was recorded in control treatment (14.42 and 16.38) at 30 DAS during both the years.

At 45 DAS, the effects of residue management practices on number of fresh nodules were found to be significant. Among residue management practices, S_1 (biochar) (49.80 and 64.55) produced the more number of fresh nodules, whereas the control treatment (36.44 and 49.85) produced the least.

Residue management practices shown significantly difference on number of fresh nodules. Among residue management practices S_1 i.e. biochar (58.60 and 77.96) recorded higher amount of number of fresh nodules and lower amount was recorded in control treatment (43.01and 59.23).

B. Number of dry nodules per plant

Effect of tillage. Tillage practices does not influence significantly on number of dry nodules at 30. Nevertheless, it was the conventional tillage (M_2) that yielded the higher number of dry nodules per plant, with 6.22 and 8.50 during 2021 and 2022, respectively. On the other hand, the minimum tillage (M_1) approach resulted in comparatively lower number of dry nodules, measuring 5.55 and 7.37 in the same respective years.

Tillage practices had not shown any significant influence on number of dry nodules during both the years, but conventional tillage (M_2) produced higher number of fresh nodules of 21.11 and 24.88 during 2021 & 2022. Lower number of dry nodules was noticed with minimum tillage (M_2) (18.91 and 22.57) in both the years at 45 DAS.

As crop advanced to 60 days, higher number of dry nodules was accrued with conventional tillage (M_2) (27.98 and 36.01) while lower number of fresh nodules was by minimum tillage (M_1) (24.47 and 33.42).

Effect of row ratios. At 30 DAS, row ratios differ significantly in terms of in number of fresh nodules, with sole pigeonpea (R_3) producing more in number of dry nodules (6.49 and 8.67) followed by (R_1) pigeonpea + maize (1:2) (5.91 and 7.96) and lower nodules was observed in (R_2) pigeonpea + maize (1:3) (5.26 and 7.18) during 2021 and 2022, respectively.

Row ratios shown differs significantly in number of dry nodules wherein higher number of dry nodules was recorded in sole pigeonpea (R_3) (22.01 and 25.36) compared other treatments i. e (R_1) pigeonpea + maize (1:2) (20.12 and 24.16) & (R_2) pigeonpea + maize (1:3) (17.90 and 21.65) during 2021 and 2022 respectively at 45 DAS.

During 2021 and 2022, row ratios found to be significant in response with number of dry nodules. Higher amount of number of dry nodules was recorded in sole pigeonpea (R_3) (28.96 and 37.72). Whereas, lower number of dry nodules was observed in R_1 i.e Pigeonpea + maize (1:3) (23.39 and 31.59) at 60 DAS.

Effect of residue management practices. Residue management practices shown significantly difference on number of dry nodules. Among residue management practices S_1 i.e. biochar (6.70 and 8.91) recorded higher number of dry nodules and lower number of dry nodules was recorded in control treatment (4.92 and 6.77) at 30 DAS during both the years.

At 45 DAS, the effects of residue management practices on number of dry nodules were found to be significant. Among residue management practices, S_1 (biochar) (22.79 and 26.98) produced the more number of dry nodules, whereas the control treatment (16.75 and 20.02) produced the least.

Residue management practices shown significantly difference on number of dry nodules. Among residue management practices S_1 i.e. biochar (29.88 and 38.73) recorded higher amount of number of dry nodules followed by S_2 i.e. Residue and lower amount was recorded in control treatment (21.86 and 29.91).

The increased number of nodules can be attributed to the loosening of the soil through ploughing. Pigeonpea plant roots that extend into a well-tilled soil with a loose and airy structure tend to foster the development of robust root nodules which ca be seen in conventional tillage. Similar results were observed by Cornel *et al.* (2016).

Higher root nodule at lower dose of fertilizer was due to the fact that the mineral nitrogen reduces nodule formation and thereby affecting symbiotic N fixation, smaller starter dose stimulates nodule formation. Sole crop received less amount nitrogen Compared to intercrop this might be the reason for increasing the number fresh nodules in sole pigeonpea crop. Similar results were found by Basu *et al*. (2008). Similar results confirmed by Dinesh *et al*. (2011).

Biochar can enhance soil structure by promoting aggregation and increasing pore space. This leads to improved water infiltration, aeration, and root penetration, creating a more favourable environment for the growth and activity of beneficial soil microorganisms, including nitrogen-fixing bacteria. Enhanced Microbial Habitat. Biochar provides a porous and stable habitat for soil microorganisms, creating a conducive environment for nitrogen-fixing bacteria to colonize and thrive. This increased microbial activity can lead to higher rates of nitrogen fixation, resulting in the development of more nodules. Similar results were observed by Carnaje and Malaluan (2015).

Table 1: Number of fresh nodules per plant of pigeonpea as influenced by different tillage and residue management practices under pigeonpea + maize intercropping system.

Treatment	30 DAS			45 DAS			60 DAS		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Tillage practices									
M_1: Minimum tillage	17.69	19.51	18.60	40.79	55.70	48.24	48.59	64.52	56.55
M_2: Conventional tillage	19.73	22.04	20.89	46.64	60.01	53.32	54.41	74.35	64.38
SEm±	0.29	0.31	-	0.72	0.56	-	0.84	1.00	-
CD (P=0.05)	NS	NS	-	NS	NS	-	NS	NS	-
Row ratios									
R_1: Pigeonpea + maize (1:2)	18.80	20.86	19.83	43.89	58.05	50.97	51.71	69.68	60.69
R_2: Pigeonpea + maize (1:3)	16.76	18.75	17.76	38.98	52.65	45.82	45.98	62.80	54.39
R_3: Sole pigeonpea	20.57	22.73	21.65	48.27	62.87	55.57	56.81	75.82	66.32
SEm±	0.34	0.35	-	0.78	0.89	-	0.91	1.09	-
CD (P=0.05)	1.10	1.13	-	2.53	2.89	-	2.95	3.55	-
Residue management practices									
S_1: Biochar	21.53	23.67	22.60	49.80	64.55	57.17	58.60	77.96	68.28
S_2: Residue	20.18	22.28	21.23	44.91	59.17	52.04	52.90	71.11	62.00
S_3: Control (No. biochar and No. Residue)	14.42	16.38	15.40	36.44	49.85	43.14	43.01	59.23	51.12
SEm±	0.28	0.28	-	0.54	0.64	-	0.63	0.76	-
CD (P=0.05)	0.82	0.82	-	1.57	1.88	-	1.84	2.21	-
Interaction	NS	NS	-	NS	NS	-	NS	NS	-

Table 2: Number of dry nodules per plant of pigeonpea as influenced by different tillage and residue management practices under pigeonpea + maize intercropping system.

Treatment	30 DAS			45 DAS			60 DAS		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Tillage practices									
M_1: Minimum tillage	5.55	7.37	6.46	18.91	22.57	20.74	24.47	33.42	28.95
M_2: Conventional tillage	6.22	8.50	7.36	21.11	24.88	23.00	27.98	36.01	31.99
SEm±	0.10	0.02	-	0.31	0.28	-	0.43	0.20	-
CD (P=0.05)	NS	NS	-	NS	NS	-	NS	NS	-
Row ratios									
R_1: Pigeonpea + maize (1:2)	5.91	7.96	6.94	20.12	24.16	22.14	26.33	34.83	30.58
R_2: Pigeonpea + maize (1:3)	5.26	7.18	6.22	17.90	21.65	19.78	23.39	31.59	27.49
R_3: Sole pigeonpea	6.49	8.67	7.58	22.01	25.36	23.68	28.96	37.72	33.34
SEm±	0.10	0.16	-	0.37	0.38	-	0.47	0.60	-
CD (P=0.05)	0.34	0.53	-	1.20	1.25	-	1.52	1.95	-
Residue management practices									
S_1: Biochar	6.70	8.91	7.80	22.79	26.98	24.89	29.88	38.73	34.30
S_2: Residue	6.05	8.13	7.09	20.49	24.18	22.33	26.95	35.50	31.22
S_3: Control (No. biochar and No. Residue)	4.92	6.77	5.84	16.75	20.02	18.39	21.86	29.91	25.89
SEm±	0.10	0.14	-	0.30	0.25	-	0.32	0.48	-
CD (P=0.05)	0.21	0.40	-	0.87	0.72	-	0.94	1.39	-
Interaction	NS	NS	-	NS	NS	-	NS	NS	-

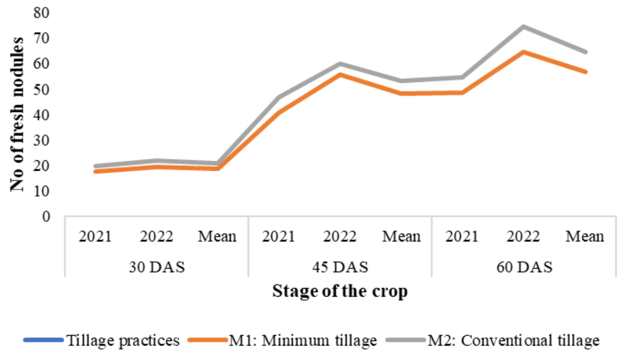

Fig. 1. Effect of tillage practices on no. of fresh nodules in pigeonpea.

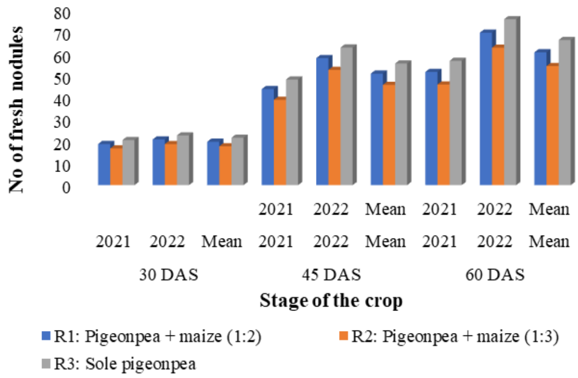

Fig. 2. Influence of row ratios on no. of fresh nodules in pigeonpea.

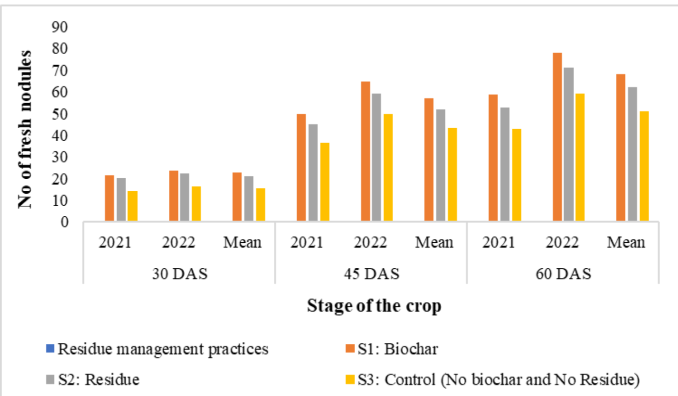

Fig. 3. Effect of residue management practices on no. of fresh nodules in pigeonpea.

CONCLUSIONS

In conclusion, conventional tillage fosters more robust root nodules, sole pigeonpea exhibits higher nodule formation and biochar application enhances nodule development through improved soil structure and microbial activity. These findings align with existing research and emphasize the significance of soil conditions in promoting effective nitrogen fixation in pigeonpea crop.

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Conflict of interest. None.

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