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Studies on Nutrient Management in Pigeon Pea [*Cajanus cajan* (L.) Millsp.] based Inter Cropping System

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ABSTRACT

Background: Pigeon pea [*Cajanus cajan* (L.) Millsp] is the sixth most important food legume of the world and grown on about 5 million hectares globally in about 50 countries. India has the largest area (4 million ha.) under pigeon pea and accounts for about 80 per cent of area of the world.

Methods: A field experiment was conducted during *kharif* season of 2015-16 at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.) to find out the suitable pigeon pea based inter cropping system and their nutrient management. The 16 treatments were tested in split plot design in which 6 cropping system were kept in main plot and 2 fertility levels in sub plots.

Result: Result showed that sole pigeon pea, sole black gram, sole green gram and sole sesame produced significantly higher seed and stover yield over intercropped mean. Under cropping system, yield attributes wear at par but the maximum grain yield of (744 kg ha^{-1}) was recorded under pigeon pea + black gram (1:1) alternate rows but stover yield (3910 kg ha^{-1}) in pigeon pea + sesame (1:1) alternate rows. As regards, the fertility levels, the yield contributing characters and yields were higher in 125% Recommended dose of Fertilizers (RDF). Intercropped black gram and intercropped green gram formed almost similar yield attributes and yields under both cropping system (1:1 and 2:2). The application of 125% RDF produced better yields attributes and yields of black gram and green gram. Intercropped and sole sesame produced and statistically equal yield contributes but seed and stover yields of sesame sole was significantly higher them intercropped sesame. Application of 125% RDF had superior yield attributes and yields of sesame. Pigeon pea + green gram (1:1 row ratio) with 125% RDF maximised the pigeon pea grain equivalent yield of 1505 kg ha^{-1}, land equivalent ratio (1.65), net profit of ₹ 84826 per ha and benefit : cost ratio (4.68) followed by pigeon pea + green gram (2:2 row ratio) with 125% RDF.

Key words: Cropping system, Gross return, LER, Net return, Pigeon pea equivalent yield, Seed yield, Stover yield.

INTRODUCTION

Pigeon pea [*Cajanus cajan* (L.) Millsp] is the sixth most important food legume of the world and grown on about 5 million hectares globally in about 50 countries. India has the largest area (4 million ha.) under pigeon pea and accounts for about 80 per cent of area of the world (Wanjari and Rathod, 2012). When pigeon pea is grown as sole crop, it is relatively inefficient because of its slow initial growth rate, indeterminate growth habit, poor source-sink relationship, poor harvest index and poor biomass production**.** Therefore it is grown as intercrop, which helps in efficient utilization of available resources for enhancing the productivity and profitability. Pigeon pea is suitable for intercropping with different crops like sorghum, pearl millet, green gram, black gram, cotton, maize, soybean, groundnut and sesame for increasing production. Pigeon pea is wide spaced crop having deep root system and initial slow rate of growth offers good scope for intercropping with short duration crop like green gram, black gram and sesame. Thus the inter cropping of pigeon pea + green gram/ black gram may be helpful in increasing total production of pulse and pigeon pea + sesame for enhancing the production of oil seed. For success of any intercropping system, plant geometry, suitable varities and fertilizer management of the component crops become important which may very with crop combination, varieties and location. Very little information is available regarding intercropping system of pigeon pea with green gram, black gram and sesame cultivars under varied row proportions (Hanumanthappa and Shrivraj, 2003). Fertilizor application are based only on individual crop basis which may not be applicable for intercropping too however, majority of farmers not apply additional nutrients for intercrops. Although any curtailment in fertilizers reduced the yield of component crops remarkably (Kumawat *et al*. 2012). Optimum fertilizer not only increases crop producting but also helps their judicious utilization. The over- and under-use of inorganic fertilizers in the intensive cropping system leads to decline in crop

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factor productivity and adversely affect soil physico-chemical proportion. Hence, these is an urgent need for research in fertilizer management that would help in making pigeon pea based intercropping system more remuneration. Nutrient management is a key issue in obtaining potential yield of both crops is any intercropping system. Nitrogen is an important major nutrient element for plants. For legume it is more useful becomes it is the main component of amino acid as well as protein. However, phosphorus is a major essential nutrients required by pulses. Thus present investigation was under taken to find out the appropriate row proportion and doses of N P K for pigeon pea based inter cropping system.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* season of 2015-16 at Agriculture farm of Mahatma Gandhi Gramodaya Vishwavidyalaya, Chitrakoot, (25°10′ N latitude, 80°52 longitude and about 190-210 meter above mean sea level). Agro ecologically Chitrakoot is characterized by semi arid and subtropical climate with hot dry summer and dry winter. The crop received 50 g mm rainfall from July to January 2016 with 28 rainy days Satna (M.P.). The soil of the experimental plot was sandy loam in texture having soil p^H 7.51, low in organic carbon (0.29%) and available nitrogen 194.32 kg ha^{-1} medium in available phosphorus 16.50 kg $ha^{-1}$and available potassium 210.25 kg ha^{-1}. Treatment consist of 6 cropping systems in main plot *viz*. pigeon pea + black gram(1:1), pigeon pea + green gram(1:1), pigeon pea + sesame(1:1) in alternate rows 60 cm apart. Pigeon pea + black gram(2:2), pigeon pea + green gram(2:2), pigeon pea + sesame(2:2) in paired planting 45/75 cm, 37.5 cm apart and two levels of fertility to intercrops in sub plot *viz*. 100% RDF and 125% of RDF. Four additional treatment of all component crops *viz*. Pure pigeon pea, pure black gram, pure green gram and pure sesame were grown for assessing the compatibility of inter cropping system, thus total 6×2 + 4 = 16 treatments were tested in split plot design in which 6 cropping system were kept in main plot and 2 fertility levels in sub plots. Pigeon pea variety Pusa-992, black gram Azad-1, green gram PDM-139 and sesame IJT-508 varieties were seed for cultivation. All crops were sown on July 02, 2015. In sole cropping pigeon pea was sown at a row spacing of 60 cm, black gram, green gram and sesame at 30 cm row spacing. Inter cropping system paired pigeon pea was sown at 45 cm apart leaving 75 cm vacant space (45 cm/75 cm) and regular pigeon pea was sown at 60 cm row spacing. In regular planting of pigeon pea, one row of black gram/green gram /sesame were sown between pigeon pea rows while in paired planting two rows of black gram/green gram / sesame were sown in the place of 75 cm vacant space. The seed rate of sole and intercropped pigeon pea was 18 kg ha^{-1}, sole and intercropped black gram and green gram was 15 kg and 7.5 kg $ha^{-1}$and sole and intercropped sesame was 5 kg and 2.5 kg ha^{-1}, respectively. The sole and intercropped pigeon pea crop was fertilized @ 20:60:20 kg NPK/ha. Sole black gram/green gram was fertilized @ 20:40:20 NPK kg ha^{-1} and sole sesame @ 40:30:20 NPK kg ha^{-1} but intercropped were fertilized with 100 and 125% of recommended dose as per treatment. The entire quantity of fertilizer in pigeon pea was given in pigeon pea rows and intercrops in intercrops rows in furrows at sowing. Thinning was done 25 days after sowing to keep the plant to plant spicing of 15 cm for pigeon pea and 10 cm for green gram, black gram and sesame, cops were protected with the application of Pendimethalin 30 EC @ 1.0 lt/ha PE application from weeds. Crops were protected from weeds, insect pest and diseases as per recommendation of crops. The pigeon pea, black gram/green gram and sesame crops were harvested on 05th Jan 2016, 25th Sep 2015 and Oct 25, 2015, respectively. The pigeon pea/ main crop equivalent yield (CEY) was calculated as per following formula (Verma and Modgel 1983):

$$CEY = Cy + C1y * \frac{Pc1}{Pc} + C2y * \frac{Pc2}{Pc} \cdots$$

Cy = Yield of the main crop, the yield of other crops commercial to its equivalent and Pc is its respective price;
C1y, C2y = Yields of intercrops /other crops which are to be converted to equivalent of main crop yield.
Pc1 and Pc2 = Their respective prices.

LER as an index of combined yield of evaluating the comparative effectiveness of two intercropping systems who worked out as per following formula (Willey and Osiru, 1972).

$$LER = \sum_{i=1}^{n} \left(\frac{Yi}{Ym} \right)$$

Where
Yi and Ym = Yield of component crops in intercropping and monoculture system, respectively.
n = Number of crop in involved the economics of component crops were estimated as per prevailing market prices.

RESULTS AND DISCUSION

Yield and yield attributes of sole crop

Yield attributes such as number of pods per plants, pod length, seeds per pod, seed weight per plant and 100 seed weight were statistically equal but numerically higher under sole pigeon pea to that of intercropped pigeon pea (Table 1). Seed and stover yield was significantly higher under sole pigeon pea over intercropped mean. It might be due to less competition and better yield attributes. Among intercropping system, pods per plant and pod length of pigeon pea were fond superior under pigeon pea + black gram (2:2 paired row) followed by pigeon pea + black gram (1:1 alternate row), contrary to that, seed weight per plant was recorded significantly higher in pigeon pea + green gram (2:2 paired row) followed by pigeon pea + sesame (1:1 alternate row). The significantly maximum seed yield of was obtained in pigeon pea + black gram (1:1 alternate row) 744 kg ha^{-1} followed by pigeon pea + green gram (2:2 paired row) 732 kg ha^{-1}. This might be owing to more space availability and

less competition due to shorter duration of black gram and green gram. This could also be ascribed due to better value of yield attributes and provided more axil points for pod formation and ultimately seed weight per plant. These results corroborate to the findings of Kumar *et al.* (2012), Pandey (2013) and Dhandayuthapani *et al*, (2015). As regards the fertility levels, application of 125% RDF produced significantly significantly higher pods per plant\, pod length per plant and seed weight per plant, seed and stover yields over 100% RDF. It was might be due to more availability of nutrients which translocation of availavel nutrients toward reproductive parts resulted higher photosynthetic efficiency. Results supported by the findings of Rathod *et al.* (2004) and Sharma *et al*, (2012).

Yield and yield attributes of intercrop

Yield attributes, *viz.* Pods per plant, seed weight per plant were found statistically at par under sole green gram them intercrop green gram. While, 100 seed weight, seed and stover yield of green gram were significantly higher under sole cropping than intercropping (Table 2). It was due to higher plant population per unit area. Under sole compared to intercrop. In both the intercropping system, almost similar yield attributes seed and stover yield of green gram was obtained but numerically higher seed yield recorded in pigeon pea + green gram (1:1 alternate row). While yield attributes *viz*, pods/plant, seed /pod, seed weight/plant and stover yield were obtained in pea + green gram (2:2 paired row) plants. The higher seed yield might be due to more availability of nutrients due to which more nutrients were trance located towards reproductive parts. Which more stover yield could be ascribed due to higher growth and yield attributes in one side and better interception of sunlight and more photosynthesis resenting more production of growth and selected parameters. Sharma *et al.* (2010) also reported the similar results. Higher level of fertility sympathy improved number of pod per plant, seeds per pod, 100 seed weight, seed and stover yield of green gram. It was probably due to more uptakes of nutrients and formation of more reproductive primodia and higher production photosynthesis more resulted more translocation to the economic parts of plants (Singh and Singh 1994) confirmed the results.

Black gram

It is evident from (Table 3) that Sole black gram produced significantly maximum pods per plant, seed weight per plant, seed and stover yield than that of intercrop black gram. It was due to higher plant population per unit area basis among intercropping, pigeon pea + black gram (2:2 paired row) had significantly highest pods per plant and seed weight per plant. Both intercropping gave statically at par seed and stover yield of black gram but numerically higher seed and

Table 1: Yield attributes and yield of pigeon pea as influenced by cropping system and fertility levels.

Treatments	Pod/ plant	Pod length (cm)	Number of seed/pod	Seed weight /plant (g)	100-seed weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Cropping system								
PP+GG (1:1 alternate row)	23.33	3.85	3.12	3.40	8.98	709	3512	16.95
PP+GG (2:2 paired row)	22.35	3.92	3.37	5.70	8.48	732	3452	17.50
PP+BG (1:1 alternate row)	26.63	3.86	3.18	3.24	9.83	744	3625	17.11
PP+BG (2:2 paired row)	28.07	4.06	3.33	3.32	9.25	723	3810	16.04
PP+SS (1:1 alternate row)	23.20	3.67	3.15	3.91	9.70	691	3910	15.26
PP+SS (2:2 paired row)	24.83	3.82	3.22	3.35	9.43	702	3224	17.96
SEm±	1.05	0.14	0.13	0.34	0.32	3.77	127.78	0.57
CD (P=0.05)	3.31	N.S.	N.S.	1.06	N.S.	11.88	402.00	1.65
Control V/S Treatment								
Treatment mean	24.74	3.87	3.23	3.82	9.31	718	3589	16.80
Sole pigeon pea	27.80	3.90	3.20	4.58	10.23	1102	6019	15.48
SEm±	1.05	0.14	0.13	0.34	0.32	3.76	127.37	0.52
CD (P=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	12.20	401.26	N.S.
Fertility levels								
100% RDF	22.88	3.79	3.14	3.53	9.11	689	3407	16.97
125% RDF	26.59	3.94	3.31	4.11	9.51	745	3771	16.63
SEm±	0.97	0.05	0.09	0.16	0.10	5.26	102.67	0.41
CD (P=0.05)	3.00	0.14	N.S.	0.48	0.32	16.19	316.30	N.S.

stover yield was found in pigeon pea + black gram (2:2 paired row) than pigeon pea + black gram (1:1 alternate row). This might be due to better interception of sunlight and more photo synthetics resulting into more production of photosynthesis and translocation to the economic parts. The results -conformed by the findings reported by Kumar and Ahlawat (1986). And Barod *et al,* (2017). Application of 125% RDF produced better yield attributes such as pods per plant, seed weight per plant, 100 seed weight and stover yields. However significantly higher seeds par plant and yield were recorded in 125% RDF. It might be due to higher availability and their uptake if nutrients that's 100% RDF. This could also be ascribed due to greater growth and yield attributes of aforesaid treatment. Corroborate finding were reported by Kumawat *et al*, (2012).

Sesame

Sole sesame produced conspicuously higher yield attributes such as capsules per plant, seed per capsule, seed weight per plant and 1000 seed weight but had significantly more seed and stover yields than inter cropped sesame (Table 4). It was due to greater plant population per unit area basis. Among the intercropping, both systems had statistically equal yield attributes *viz* capsules per plant, seeds per capsule, seed weight per plant, 1000 seed weight as well as seed and stover yield. It was due to similar plant population and yield attributes of sesame in both system of cropping. This could also be explained that sesame is a long duration crop under on which pigeon pea crop reaches at flowering stage and sesame under both the cropping system, (1:1 and 2:2) behave this similar pattern resulted in

Table 2: Yield attributes and yields of green gram as affected by cropping system and fertility levels.

Treatments	Pods / plant	Number of seeds / pod	Seed weight / plant (g)	100-seed weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Cropping system							
PP+GG (1:1 alternate row)	9.65	8.67	3.78	2.52	442	1333	24.89
PP+GG (2:2 paired row)	13.03	7.95	4.25	2.53	397	1502	21.76
SEm±	0.57	0.36	0.26	0.05	15.18	111	1.23
CD(P=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Control V/S Treatment							
Treatment mean	11.34	8.31	4.02	2.53	420	1417	23.33
Sole green gram	13.73	7.70	4.55	2.83	503	2296	17.93
SEm±	0.64	0.40	0.29	0.05	16.98	52.34	1.37
CD(P=0.05)	N.S.	N.S.	N.S.	0.13	80.10	174.84	N.S.
Fertility levels							
100% RDF	9.50	7.83	3.72	2.42	383	383	23.28
125% RDF	13.18	8.78	4.31	2.63	456	456	23.37
SEm±	0.85	0.17	0.29	0.03	12.51	12.51	0.65
CD(P=0.05)	3.32	0.66	N.S.	0.09	48.83	112.95	N.S.

Table 3: Yield attributes and yields of black gram as affected by cropping system and fertility levels.

Treatments	Pods / plant	Number of seeds / pod	Seed weight / plant (g)	100-seed weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Cropping system							
PP+BG (1:1 alternate row	3.30	4.58	1.67	3.37	245	583	30.43
PP+BG (2:2 paired row)	5.77	5.50	2.93	3.30	283	908	24.61
SEm±	0.27	0.47	0.11	0.07	20.83	105	1.69
CD (P=0.05)	1.64	N.S.	0.70	N.S.	N.S.	N.S.	N.S.
Control V/S Treatment							
Treatment mean	4.54	5.04	2.30	3.33	264	740	27.52
Sole black gram	8.77	6.17	3.33	3.63	425	1407	23.64
SEm±	1.28	0.53	0.13	0.13	23.28	116.91	1.88
CD (P=0.05)	1.81	N.S.	0.17	N.S.	141.63	570.45	N.S.
Fertility levels							
100% RDF	3.87	4.68	2.02	3.22	244	640	28.99
125% RDF	5.20	5.40	2.57	3.45	284	849	26.05
SEm±	0.40	0.15	0.30	0.09	3.73	49.23	0.87
CD (P=0.05)	N.S.	059	N.S.	N.S.	14.56	N.S.	N.S.

almost sesame yield. (Hirwe and Mahajan (2012). Application of 125% RDF significantly improved capsules per plant and no of seed weight. Numerically higher but statistically equal seed yield and stover yield was recorded under 125% RDF. Seed yield was recorded 32 kg/ha higher under 125 % RDF than 100% RDF. This might be due to higher availability and uptake of nutrients.

Pigeon pea equivalent yield and land equivalent ratio

The highest pigeon pea equivalent yield with one alternate row or two paired row at either of the row spacing *i.e.* 60 cm or 75 cm of pigeon pea produced higher value of Pigeon pea equivalent yield as compared to the sole Pigeon pea grain yield. Pigeon pea equivalent yield was recorded remarkably higher under pigeon pea + green gram in 1:1 row ratio with 125% RDF 1505 kg ha^{-1} closely followed by pigeon pea + green gram in 2:2 paired row with 125% RDF 1411 kg ha^{-1} as compared 36.56 and 28.03% higher than sole pigeon pea (Table 5). It was due to additional yield of green gram. Similar results were reported by Kumar *et al.* (2003), Kumar *et al. (*2012), Patidar (2015).

Economics

It is evident from (Table 5) that highest gross income (₹107821 ha^{-1}) and net return (₹ 84826 ha^{-1}) was achieved under pigeon pea + green gram (1:1 alternate row) with 125% RDF followed pigeon pea + green gram (2:2 paired row) with 125% RDF ₹102500 ha^{-1} and ₹79503 ha^{-1}. It was

Table 4: Yield attributes and yields of sesame as affected by cropping system and fertility levels.

Treatments	Number of capsule/ plant	Seeds / capsule	Seed weight / plant (g)	1000-seed weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Cropping system							
PP+SS (1:1 alternate row)	16.75	35.00	0.947	2.51	253.00	578.00	30.52
PP+SS (2:2 paired row)	18.03	37.83	0.923	2.61	282.00	716.00	28.33
SEm±	2.65	3.43	0.040	0.05	18.89	39.05	0.47
CD (P=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Control V/S Treatment							
Treatment mean	17.39	36.42	0.935	2.56	267.00	647.00	29.43
Sole sesame	22.90	43.67	1.036	2.72	367.00	1070.0	25.07
SEm±	2.96	3.59	0.046	0.06	11.27	43.66	0.52
CD (P=0.05)	N.S.	N.S.	N.S.	N.S.	45.00	265.66	3.18
Fertility levels							
100% RDF	15.07	37.50	0.913	2.51	251.00	594.00	30.09
125% RDF	19.72	35.33	0.957	2.61	283.00	700.00	28.76
SEm±	0.96	2.54	0.012	0.01	21.31	51.75	0.76
CD (P=0.05)	3.74	N.S.	N.S.	0.03	N.S.	N.S.	N.S.

Table 5: Pigeon pea grain equivalent yield, LER and Economics of cropping system under two fertility levels.

Treatments	PP equivalent yield (kg/ha)	LER	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
T_1 : C_1 F_1 (PP + UB) (1:1 alternate row)	1049	1.14	22354	69308	46954	3.09
T_2 : C_1 F_2 (PP + UB) (1:1 alternate row)	1124	1.47	22997	75349	52352	3.27
T_3 : C_2 F_1 (PP + SS) (1:1 alternate row)	894	1.22	20700	58820	38120	2.83
T_4 : C_2 F_2 (PP + SS) (1:1 alternate row)	1035	1.49	21061	67970	46919	3.22
T_5 : C_3 F_1 (PP + MB) (1:1 alternate row)	1342	1.46	22354	96730	74376	4.32
T_6 : C_3 F_2 (PP + MB) (1:1 alternate row)	1505	1.65	22995	107821	84826	4.68
T_7 : C_4 F_1 (PP + UB) (2:2 paired row)	1075	1.23	22354	73377	51023	3.28
T_8 : C_4 F_2 (PP + UB) (2:2 paired row)	1215	1.30	22997	82376	59379	3.58
T_9 : C_5 F_1 (PP + SB) (2:2 paired row)	934	1.36	20700	61144	40444	2.95
T_{10} : C_5 F_2 (PP + SB) (2:2 paired row)	969	1.56	21061	63993	42932	3.03
T_{11} : C_6 F_1 (PP + MB) (2:2 paired row)	1266	1.38	22354	91013	68659	4.07
T_{12} : C_6 F_2 (PP + MB) (2:2 paired row)	1411	1.54	22997	102500	79503	4.45
T_{13} : PP (Sole)	1102	1.00	23898	103647	79749	4.33
T_{14} : BG (Sole)	656	-	19403	45220	25817	2.32
T_{15} : Sesame (Sole)	339	-	15978	22060	6083	1.37
T_{16} : GG (Sole)	773	-	19403	54850	35447	2.82

attributed to additional yield of green gram and lesser cost of cultivation. These results may be supported by the findings of Prasad (1994), Sharma and Guled (2012) and Kumawat *et al.* (2012). Land equivalent ratio of all intercropping with fertility management treatment was recorded more than one, indicating the superiority of intercropping system as compared as to the sole crop of pigeon pea, green gram, black gram and sesame. Land equivalent ratio was estimated higher under pigeon pea + green gram (1:1 alternate row) of 60 cm with 125% RDF (1.65) followed by pigeon pea + sesame (2:2 paired row) at 45/75 with 125% RDF (1.56). The higher LER under these intercropping systems may be due to better planting geometry and spatial arrangements that might have avoided consistence of the peak period of growth of component crops and sufficient fertilizer was applied to all the component crops. This might have helped for efficient use of natural recourses by the comment crops under intercropping system. It indicated that the intercropping of pigeon pea and intercrops in any ratio and fertility levels is more beneficial than their sole stands and there was mutual compensation between both the crops. Dhandayuthapani *et al*. (2015) and Barod *et al*. (2017) also reported the similar results. Return per rupee invested (benefit : cost ratio) was estimated higher under pigeon pea + green gram (1:1 alternate row) at 60 cm with 125% RDF (4.68) followed by pigeon pea + green gram (2:2 paired row) at 45/75 cm with 125% RDF (4.45) as compared to 4.3 to pigeon pea sole (Table 5). It was because of higher gross return and relatively lesser cost of cultivation than sole pigeon pea. Similar results was found by Kumawat *et al*. (2012) and Patidar (2015).

CONCLUSION

Based on the study it can be concluded that pigeon pea + green gram(1:1 alternate rows) at 60 cm apart with 125% of recommended dose of fertilizer (25 kg N + 50 kg P_2O_5 + 25 kg K_2O/ha) was found most productive and profitable system for Kymore Plateau of Madhya Pradesh.

Conflict of interest: None.

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