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Growth and productivity of maize (*Zea mays* L.) and Pigeonpea [*Cajanus cajan* (L.) Millsp.] under intercropping system as influenced by row ratio and nutrient management practices

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Abstract
A field experiment was carried out during *kharif* season of 2016-17 and 2017-18 at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.) to assess the effect of row ratio and nutrient management practices on growth parameters, yield and productivity of maize and pigeonpea under intercropping system. Growth parameters *viz.* plant height and dry weight/plant at 25 DAS of maize and plant height, trifoliate leaves at 60 DAS and primary and secondary branches of pigeonpea were observed statistically at par but markedly higher under 2:2 row ratio of maize + pigeonpea intercropping system during 2016-17 and 2017-18. However, dry weight/plant of pigeonpea and grain yield of maize and pigeonpea were obtained significantly greater under 2:2 row ratio of maize + pigeonpea system. LER and maize equivalent grain yield (CEY) was also estimated significantly superior under maize + pigeonpea (2:2 paired) system during two years. Maize + pigeonpea (2:2) system gave 659 kg (10.87%) and 765 kg (12%) more crop equivalent grain yield (CEY) over 1:1 row ratio of same system during two respective years.
Application of 75% RDF to main crop + FYM @ 5 t/ha recorded significantly greater growth parameters of maize *viz.* plant height and dry weight/plant at 25 DAS and pigeonpea i.e. plant height, dry weight/plant, trifoliate leaves, primary and secondary branches which exhibited statistically at par to 100% RDF to main crop. LER and CEY were obtained significantly higher under 75% RDF to main crop + FYM @ 5 t/ha and statistically on par to 100% RDF to main crop except LER in 2017-18. CEY was noted higher under 75% RDF to main crop + FYM 5 t/ha to tune of 338 kg (4.48%) and 364 kg (4.82%) over 100% RDF to main crop respectively during consecutive years. Grain yield of intercrop pigeonpea was significantly reduced compared to pure pigeonpea (1210 and 1299 kg/ha) which showed almost same under 75% RDF + FYM 5 t/ha to main crop (1305 and 1394 kh/ha) during two years.

Keywords: Maize, pigeonpea, growth, yield, maize equivalent grain yield, LER, intercropping system, nutrient management

Introduction
Maize (*Zea mays* L.) is known as miracle crop accounts third position among the cereals after rice and wheat across the globe. It is a major food crop in India after rice and wheat. However, it is the fifth most important food crops in Madhya Pradesh, with an acreage of 1.5 million ha, production of 3.91 million tonnes and productivity 2627 kg/ ha (Anonymous, 2020-21). Maize and pigeonpea is an important intercropping system being grown in different part of India including Kymore Plateau region of Madhya Pradesh. However, it is having the possibility of intercropping of pigeonpea in maize crop for securing the higher system productivity besides addressing the soil health issues. Being different maturing habit, growth and rooting pattern, nutrient and water requirement these crops make them suitable to grow as intercrop with pigeonpea. Maize provides sufficient row space, which can be profitably utilized for growing any leguminous crop with distinct growth pattern, However, there is no specific row ratio of maize + pigeonpea to accommodating whole population of base crop as well intercrop. The combined use of nutrient sources for meeting the nutrient requirement of both the crops was also targeted to sustain the soil health. The integration of organic manures and chemical fertilizers would be better option than the individual application of both. Balanced and efficient application with combine use of organic manures and chemical fertilizers are vital in achieving high yield with reduced cost of production.

Therefore, there is need to assess effect of judicious combination of organic manures and chemical fertilizers on crop performance, nutrient uptake and soil physiochemical properties of maize and pigeonpea intercropping systems. Hence, keeping in the fact and view, the present study was carried out to study the effect of maize + pigeonpea intercropping in different row ratio for achieving the higher system productivity and arresting soil health deterioration.

Material and Method

A field experiment was carried out during *kharif* season of 2016-17 and 2017-18 at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.) India ($25^0$10' N latitude and $80^0$32' E longitude and about 190-210 meter above mean sea level). The average annual rainfall of Chitrakoot is 950 mm while, crop received 870 mm and 820 mm rainfall during two respective years. The soil is sandy loam in texture with low organic carbon (0.29% and 0.24%) and nitrogen (193.43 kg N/ha and 201.6 kg N/ha), medium in phosphorous (16.72 Kg P/ha and 20.11 kg P/ha) and potassium (207.28 kg K/ha and 201.5 kg K/ha). The soil was about neutral in reaction with 7.44 to 7.46 soil pH and Electrical conductivity of the soil was 0.30 to 0.32 dSm^{-1}.

In the present study, two intercropping system of C_1: maize + pigeonpea (1:1) and C_2: maize + pigeonpea (2:2 paired) row ratio were tried under five practices of nutrient management N_1**:**100% N equivalent to main crop from organic manure (OM), N_2**:**75% N equivalent to main crop from OM, N_3**:**75% RDF to main crop, N_4**:**75% RDF to main crop + FYM @ 5 t/ha, N_5**:**100% RDF to main crop and two additional treatment of sole maize and pigeonpea were included. Thus 12 treatment combinations (5X2 +2) replicated thrice in a strip block design. Varieties PAC 712 (maize) and UPAS 120 (pigeonpea) with the row spacing of 60 cm to both crop (normal), 30 cm to (1:1) and 30/90 cm paired planting were maintained. Sowing of pigeonpea was done between the pairs of maize row by reducing row spacing between two rows of a pair up to 30 cm instead of normal spacing of 60 cm. The seeds were drilled manually in the furrow. Seed rate of pigeon pea was 20 kg/ha and for pigeon pea was 20 kg/ha used respectively. Thinning was done at 20 days after sowing to keep the plant to plant spacing of 20 cm for maize and 15 cm for pigeon pea. The 100 per cent NPK (for maize) is characterized by 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} and 100% N equivalent by organic sources *viz.* 24 t/ha FYM. Irrigation was applied as per need of crop. Weeds were kept below the threshold level by two hand weeding 30 and 60 days after sowing. The data on growth and yield of maize and pigeonpea was recorded as per standard procedure.

Land equivalent ratio (LER) was estimated as per procedure given by Willey & Osiru (1972) [15].

Maize equivalent grain yield was calculated with the following formula

$$\text{MCEY (kg/ha)} = \text{Yield of maize (kg)} + \frac{\text{Seed yiled of pigeonpea (kg/ha)} \times \text{Sole price ofpigeonpea(₹/kg)}}{\text{Sole price of maize grain (₹/kg)}}$$

All the data were subjected to statistical analysis by using the technique analysis of variance (ANOVA) to test the significance of treatments. Critical difference (CD at P=0.05) was used to determine whether means differenced significant or not (Gomez and Gomez, 1984) [5].

Results and Discussion

Effect on Maize

Growth parameter

Growth characters *viz* plant height was observed numerically higher under maize + pigeonpea (2:2 paired row) however plant dry matter was registered significantly more in maize + pigeonpea (2:2 paired row) over maize + pigeonpea (1:1) at harvest stage of crop during two years. It might be due to better utilization of natural resources which leads to better plant growth of maize crop. The results are in conformity with findings of Kumar *et al.* (2021) [9].

Among nutrient management practices, plant height and dry matter/plant were recorded significantly superior under N_4:75% RDF to main crop + FYM 5t/ha and statistically at par with N_5:100% RDF to main crop during two respective years. It might be due to direct effect of integrated application of inorganic and organic source of nutrient. This could also be ascribed owing to better utilization of sufficient nutrient and grew better than other treatment. The sufficient nutrient supply throughout the crop growth was due to slow release of nutrient from organic manure at early stage of crop under N_4: 75% RDF to main crop + FYM 5t/ha which might have helped the crop to attain its full vegetative growth and has been reflected in terms of dry matter production. The results are in conformity with findings of Kheroar and Patra (2013) [6], Singh *et al.* (2017) [11], Mahapatra *et al.* (2018) [12] and Kumar *et al.* (2021) [9].

The pure cropping system of maize registered highest plant height and dry matter than that of rest of inter cropping treatment mean at 20 DAS and harvest stage during two years. It might be because of more space avail by pure crop while, intercrop plant face some degree of competition with comparative lower spacing which reduced growth parameters of maize crop.

Yield

The grain yield of maize was significantly improved under C_2: maize + pigeon pea (2:2 paired row) over C_1: maize + pigeon pea (1:1) in both years of study but stover yield of maize was statistically at par with intercropping system. Though stover yield of maize was found conspicuously higher under C_2: maize + pigeon pea (2:2). It might be owing to better growth and superior yield attributes of maize with pigeonpea intercropping systrm. Similar variations in yield of maize due to different planting pattern in maize + legume intercropping were also presented by Alhaji (2008) [1], Gabatshele *et al.* (2012) [4], Jat *et al.* (2014) and Kumar *et al.* (2021) [9].

In nutrient management practices, addition of 75% RDF to main crop + FYM @ 5 t/ha obtained significantly superior grain yield and stover yield and statistically at par to N_5**:**100% RDF to main crop. This could be ascribed due to better growth parameter and greater value of yield attributes in concerning treatment. This might also be owing to at par nutrient application with slowly available nutrient and formation of organic complex by provide integration of organic and inorganic fertilizer. These results are corroborated to the findings of Kheroar and Patra (2013) [6], Tomar *et al.* (2017) [14], Singh *et al.* (2017) [11] and Kumar *et al.* (2021) [9].

The sole maize produced markedly more grain and stover yield compared to rest of treatment mean. This might be due to some of competition faced by intercrop maize but the value did not reach up to level of significant, however peak demand

of nutrient and water is differed in maize and pigeonpea intercropping system. These results are corroborated to findings of Tomar *et al.* (2017) [14] and Kumar *et al.* (2021) [9].

Effect of Pigeon pea

Growth parameter

Growth parameters of pigeonpea *viz* plant height, trifoliate leaves, primary and secondary branches were found higher in maize + pigeon pea (2:2 paired row) intercropping during both the years. However, plant dry matter was found significantly greater under maize + pigeonpea (2:2) system over the maize + pigeonpea (1:1) row ratio during two respective years. It might be due to more competition of pigeon pea plants faced with maize under 1:1 row planting while paired planting availed more side space which was properly utilized sunlight and space by intercropping pigeonpea plant. Similar results were reported by Pandey *et al*. (2013) [13] and Kumar *et al*. (2013) [17].

Addition of 75% RDF to main crop + FYM @ 5 t ha (N_4) produced significantly higher plant height, number of trifoliate leaves/plant, dry matter /plant, primary and secondary branches/plant which exhibited statistically at par to N_5:100% RDF to main crop during 2016-17 and 2017-18. It might be due to better nourishment and more uptake to nutrient of pigeon pea plants. The results are corroborated with the findings of Pandey *et al*. (2013) [13], Kumar *et al*. (2013) [17] and Kumawat *et al.* (2015).

Although sole cropping of pigeonpea recorded statistically at par growth parameters plant height, dry matter, trifoliate leaves, primary and secondary branches with inter cropping treatment mean but these were markedly higher under sole pigeonpea than intercrop pigeonpea at 20 DAS and harvest stage during two years. This might be because of initial slow growth and shorter duration of pigeonpea which has reduced the competition of intercrop pigeonpea.

Yield

The grain yield of intercrop pigeonpea was found significantly higher under maize + pigeonpea (2:2 paired row) over C_1: maize + pigeon pea (1:1). However, stover yield of pigeon pea was noted markedly more under maize + pigeon pea (2:2) during two years. This might be due to better accommodation of pigeonpea plant under 2:2 row ratio which provides an opportunity to proper growth and development and promoted more mobilization of photosynthates towards sink and resulted higher grain yield. Similar variations in yield of pigeonpea due to different planting pattern in maize + legume intercropping were also reported by Behera *et al.* (1994) [3] and Kumar and Kushwaha (2018) [8].

In nutrient management practices, significantly superior grain and stover yield was noted under N_4: 75% RDF + FYM @ 5t/ha to main crop which showed statistically at par to N_5: 100% RDF to main crop, Such increase could be ascribed due to higher value of yield attributes of intercrop pigeon pea. The results are corroborated with the findings of Ahamad *et al.* (2017) [2].

The sole cropping of pigeonpea obtained significantly higher grain yield than that intercrop treatment mean. This might be due to better growth parameters of sole crop than intercrop pigeonpea. The results are corroborated with the findings of Ahamad *et al.* (2017) [2] and Kumar and Kushwaha (2018) [8].

CEY and LER

The highest LER and CEY were recorded significantly higher under C2 maize + pigeonpea (2:2) intercropping over C1 maize + pigeonpea (1:1) in both years. This might be owing to significantly superior grain yield of maize as well as pigeonpea under 2:2 row ratio and higher price of pigeonpea grain.

In nutrient management practices, significantly highest CEY and LER were obtained under N_4 75% RDF to main crop + FYM @ 5t/ha except LER at 2017-18. This could be ascribed due to almost similar grain yield of intercrop of as well pigeonpea under N_4: 75% RDF + FYM @ 5t/ha to main crop compared with pure system of respective crop. Similar findings were also reported by Kheroar and Patra (2013) [6] under pigeon pea based intercropping.

Table 1: Growth parameters of maize as influenced by intercropping systems and nutrient management

Treatments	Plant height (cm) at harvest		Dry weight (g) at 25 DAS	
	2016-17	2017-18	2016-17	2017-18
Intercropping systems				
C_1: Maize + Pigeon pea (1:1)	182.8	190.6	10.70	11.32
C_2: Maize + Pigeon pea (2:2)	188.2	193.1	11.66	12.62
S.Em+	2.47	4.58	0.42	0.46
CD (P=0.05)	NS	NS	NS	NS
Nutrient Management Practices				
N_1**:** 100% N equivalent to main crop from OM	179.1	185.6	9.95	10.63
N_2**:** 75% N equivalent to main crop from OM	172.4	179.7	8.40	8.83
N_3**:** 75% RDF to main crop	183.4	190.5	11.58	12.22
N_4**:** 75% RDF to main crop + FYM@5 t/ha	199.2	204.2	13.22	14.48
N_5**:** 100% RDF to main crop	193.3	199.2	12.95	13.69
S.Em+	4.49	4.54	0.26	0.26
CD (P=0.05)	12.84	12.96	0.73	0.74
Sole Vs Rest				
Sole maize	198.2	206.4	12.82	13.52
Treatment mean	185.5	191.8	11.18	11.97
S.Em+	6.38	7.51	0.54	0.52
CD (P=0.05)	NS	NS	NS	NS

Table 2: Growth parameters of pigeon pea as influenced by intercropping systems and nutrient management

Treatments	Plant height (cm) at harvest		Dry weight (g) at 60 DAS		Trifoliate leaves at 60 DAS		No. of primary branches		No. of secondary branches	
	2016-17	2016-17	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Intercropping systems										
C_1: Maize + Pigeon pea (1:1)	174.63	176.37	56.83	58.67	76.16	81.17	10.59	10.92	7.06	7.14
C_2: Maize + Pigeon pea (2:2)	175.56	178.21	60.33	63.29	80.03	82.34	10.76	10.98	7.14	7.75
S.Em+	2.56	5.70	0.74	0.86	1.72	3.05	0.23	0.37	0.11	0.24
CD (P=0.05)	NS	NS	2.91	3.39	NS	NS	NS	NS	NS	NS
Nutrient Management Practices										
N_1**:** 100% N equivalent to main crop from OM	174.18	176.66	55.23	56.92	75.86	80.55	10.17	10.56	6.43	7.05
N_2**:** 75% N equivalent to main crop from OM	160.77	163.50	50.82	51.65	72.31	77.77	9.89	10.22	6.25	6.33
N_3**:** 75% RDF to main crop	176.50	177.75	59.62	62.08	76.89	81.31	10.34	10.81	6.99	7.37
N_4**:** 75% RDF to main crop + FYM@5 t/ha	186.32	186.50	65.21	68.75	84.53	86.55	11.52	11.61	8.11	8.33
N_5**:** 100% RDF to main crop	177.70	179.03	62.04	65.50	80.90	82.60	11.47	11.56	7.72	8.16
S.Em+	3.40	4.06	1.76	2.28	2.34	1.66	0.21	0.20	0.14	0.18
CD (P=0.05)	9.68	11.59	5.03	6.53	6.68	4.74	0.59	0.57	0.40	0.52
Sole Vs Rest										
Sole Pigeonpea	181.80	185.20	64.80	69.30	82.20	88.58	11.58	11.71	7.82	8.26
Treatment mean	175.09	177.29	58.58	60.98	78.10	81.75	10.67	10.95	7.10	7.45
S.Em+	5.13	7.80	2.42	3.12	3.52	3.75	0.35	0.45	0.21	0.34
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Grain and stover yield of maize and pigeonpea as influenced by intercropping systems and nutrient management

Treatments	Maize				Pigeonpea			
	Grain yield (kg/ha)		Stover yield (kg/ha)		Grain yield (kg/ha)		Stover yield (kg/ha)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Intercropping systems								
C_1: Maize + Pigeon pea (1:1)	3316	3386	6678	6724	989	1078	5287	5404
C_2: Maize + Pigeon pea (2:2)	3644	3789	6892	6920	1109	1209	5357	5588
S.Em+	69.30	69.45	82.72	250.3	25.30	32.39	108.84	108.82
CD (P=0.05)	272.1	272.6	NS	NS	99.31	127.1	NS	NS
Nutrient Management Practices								
N_1: 100% N equivalent to main crop from OM	3328	3448	6553	6578	963	1046	5092	5276
N_2: 75% N equivalent to main crop from OM	2911	2971	5994	6009	719	784	4234	4516
N_3: 75% RDF to main crop	3476	3581	6924	7008	1023	1174	5387	5525
N_4: 75% RDF to main crop + FYM@5 t/ha	3916	4042	7405	7430	1307	1395	6001	6133
N_5: 100% RDF to main crop	3770	3893	7048	7084	1237	1317	5899	6029
S.Em+	119.3	90.4	166.6	142.3	36.35	31.49	152.3	204.4
CD (P=0.05)	340.7	258.0	475.5	406.1	103.72	89.88	434.5	583.2
Sole Vs Rest								
Sole	3993	4099	7481	7558	1212	1301	5869	6128
Treatment mean	3480	3587	6785	6822	1050	1143	5322	5495
S.Em+	170.9	137.3	233.3	312.0	53.89	52.44	227.13	288.85
CD (P=0.05)	NS	NS	NS	NS	161.50	157.10	NS	NS

Table 4: LER and CEY as influenced by intercropping and nutrient management treatment

Treatments	CEY		LER	
	2016-17	2017-18	2016-17	2017-18
Intercropping systems				
C_1: Maize + Pigeon pea (1:1)	6059	6372	1.65	1.65
C_2: Maize + Pigeon pea (2:2)	6718	7138	1.83	1.85
S.Em+	57.96	159.2	0.02	0.04
CD (P=0.05)	227.5	625.1	0.06	0.16
Nutrient Management Practices				
N_1**:**100% N equivalent to main crop from OM	5995	6345	1.63	1.65
N_2**:**75% N equivalent to main crop from OM	4901	5142	1.32	1.33
N_3**:**75% RDF to main crop	6310	6835	1.71	1.78
N_4**:**75% RDF to main crop + FYM@5 t/ha	7536	7907	2.06	2.06
N_5**:**100% RDF to main crop	7198	7543	1.97	1.96
S.Em+	163.2	190.5	0.04	0.02
CD (P=0.05)	465.9	558.3	0.13	0.07
Sole Vs Rest				
Sole maize	-	-	1.00	1.00
Treatment mean	6388	6755	1.74	1.75
S.Em+			0.06	0.05
CD (P=0.05)			NS	NS

Conclusion

Thus, it can be concluded that maize sown in 2:2 paired row with pigeon pea under 75% RDF to main crop + FYM @ 5 t/ha treatment was found best treatment for higher growth yield and productivity of maize and pigeonpea under intercropping system in Kymore Plateau region of Madhya Pradesh.

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