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Impact of cropping pattern on growth, yield attributes and system productivity of citronella (*Citronella winterianus*) - pulses intercropping system in Central India

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ABSTRACT

A field experiment was conducted at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during 2010-11 and 2011-12 to study the Impact of cropping pattern on growth, yield attributes and system productivity of citronella (*Citronella winterianus* L.) – pulses intercropping system in Central India. There was significant superiority in growth, yield attributes and yield of sole cropping as compared to their intercropping. On an average significantly higher herbage yield of first (202.74 q/ha) and second cutting (161.15 q/ha) was recorded in citronella sole cropping followed by 2:1 row ratio of citronella + pigeonpea. However, the citronella sole cropping gave significantly highest citronella equivalent oil yield and net returns than other cropping systems. The higher B: C ratio was recorded under citronella: pigeonpea 2:2 row ratio (12.6) in 2010-11 and citronella: pigeonpea (2:1) (8.75) in 2011-12 than other cropping systems. The higher LER values in citronella: pigeonpea intercropping, i.e.1.03 to 1.08, clearly indicate 3 to 8% advantage over their sole stand. Citronella sole recorded the highest crop profitability (₹ 753 to 837 ha/day).

Key words: Citronella, Crop profitability, Cropping system, Land equivalent ratio, Pigeonpea, System productivity

Citronella (*Citronella winterianus* L.) oil is one of the major essential oils. It has a rose like odour and bitter taste. It is mainly used in the perfumery and cosmetic industry. Citronella oil is a raw material for production of geranial, citronellal, hydroxy-citronellal and other similar high value perfumery bases. It is also widely used as a starting material for various aromatic chemicals used in scented soaps, sprays, deodorants, detergents, polishes, mosquito repellants etc. The essential oil industry in India has witnessed a remarkable growth since the early 70's from a production of around 50 tpa in 1973, the industry registered a ten-fold increase in production and the current production is about 700 tpa. The present demand is placed at around 3 400 tonnes/year. It may be estimated that the global demand could exceed 6 500 million tonnes/year partly the synthetic equivalents at present about 1 800 million tonnes is being produced in the world out of which India produce about 600 million tonnes/year.

In India, pulses are being grown on about 23.6 m ha and production is about 14.9 mt having an average productivity of 0.63 tonne/ha (The Hindu, Survey of Indian Agriculture, 2011a). The productivity is much lower than other pulse producing countries of the world. India needs to import pulses to the tune of 2 mt every year (₹ 3 000 crores) to meet its domestic requirement. Nevertheless, to meet the requirement at least 23.88 mt of pulses is required by 2015. However, to make the nation pulse sufficient, productivity level of pulses needs to be increase substantially to 1.2 tonnes/ha by 2020 (The Hindu, Survey of Indian Agriculture, 2011b).

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is the second most important pulse crop of India after chickpea, which is predominantly grown on marginal lands and is usually intercropped with cereals under rainfed conditions. Pigeonpea ranks second in both acreage (3.58 m ha) and production (2.74 mt) among the pulses in India with average productivity of 765 kg/ha (Ansari *et al.* 2012). Besides, fixing atmospheric N_2, pigeonpea sheds most of its leaves at maturity and improves soil organic matter. Limited and erratic rainfall in rainfed areas makes pigeonpea vulnerable to moisture stress conditions during later part of its growth, resulting in severe yield reduction. At present, more than 92% of the area under pulses is confined to unirrigated areas, and in future, the bulk of pulse production will continue to come from unirrigated areas. Therefore, any plan for increasing pulse production in the country should be based on an efficient approach for improved productivity of these crops under rainfed conditions rather than only the use of high inputs. It would be justifiable to accept that

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Table 1 Soil fertility status of experimental field before sowing and after harvesting

Treatment	Soil properties													
	Before sowing							After harvesting (mean of two years)						
	Soil pH	Soil EC (dS/m)	BD mg/ (m^3)	OC (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Soil pH	Soil EC	BD (mg/m^3)	OC (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Citronella sole	8	0.25	1.37	0.45	177	19.5	160	8.1	0.26	1.4	0.43	165.4	18.2	155.3
Pigeonpea sole	8	0.25	1.37	0.45	177	19.5	160	7.7	0.23	1.29	0.47	183.4	20.8	163.2
C:P (1:1)	8	0.25	1.37	0.45	177	19.5	160	7.8	0.24	1.32	0.46	180.2	19.9	162.3
C:P (2:1)	8	0.25	1.37	0.45	177	19.5	160	7.9	0.24	1.33	0.45	178.1	19.8	162.1
C:P (2:2)	8	0.25	1.37	0.45	177	19.5	160	7.8	0.24	1.33	0.46	179.2	20	161.1

intercropping system will attract increasing attention to overcome ecological constraints. However, with the changing scenario of crop improvement and diversification, there is a need to relook and investigate low cost technology with medicinal and pulses crops.

MATERIALS AND METHODS

The field experiment was conducted at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (UP) India, during 2010-11. The mean annual precipitation were about 818 mm. May and June are the hottest with maximum temperature ranging between 23.4 and 37.7 ^{0}C during crop period, while there was a drop in temperature from September onwards. January was the coldest month of the year with a minimum temperature of 7 ^{0}C. The relative humidity attains the maximum value 93% during south-west monsoon and the minimum of 28% during summer months. The soil was sandy loam in texture with medium in available N, available P and available K (Table 1). The experiment was laid out in randomized block design including fice cropping system (C_1- Citronella sole, C_2-pigeonpea sole, C_3-citronella + pigeonpea in 1:1 row ratio, citronella + pigeonpea in 2:1 row ratio and citronella + pigeonpea in 2:2 row ratio) under four replications. The crop was sown/transplanted after pre-sowing irrigation. Root slips of Citronella variety BIO 13 were used. After removing upper sheath the root slips was transplanted in line on 30 July, 2010 at a spacing of 60 × 60 cm. Pigeonpea variety (Amar) was used @ 15 kg/ha. The crop was sown in line on 3 August 2010 at a spacing of 60 × 20 cm. Crops were grown as per recommended package of practices. The recommended dose of fertilizer for citronella crop @ 150 kg N, 80 Kg P_2O_5 and 40 kg K_2O/ha was supplied through Urea, DAP and MOP. The full dose of P_2O_5, K_2O supplied at the time of sowing and N was applied in 4 equal split doses. The dose applied one month after planting and remaining after each harvest. Citronella and pigeonpea were sown during first week of August 2010. Pigeonpea matured in first fortnight May 2011. While, first cutting of citronella done on second week of March and 2nd cutting last week of June 2011.

RESULTS AND DISCUSSION

Effect of cropping system on citronella

The cropping systems significantly affected the growth attributes (plant height and number of tillers/m row length) at 60 DAS and 120 DAS (Table 2) in both year of experimentation. This may be due to optimum spacing available for the plants in sole cropping as compared to other combinations of cropping systems. Such higher growth performance in sole crop as compared to intercropping system has also been observed by Patra *et al.* (2005). It is also clear from the result that next to citronella sole, C:P (2:1) row ratio treatment was also recorded significantly superior in the characters like plant height at 60 and 120 DAS and number of tillers at 60 DAS over all the treatments and at par with C:P (1:1). The intercrop was affected due to the presence of inter and intra-specific competition between main crop and the intercrop (pigeonpea) for growth resources such as nutrients, moisture and solar radiation due to change in crop geometry as compared to sole crop. The results of the present investigation are in close conformity with the

Table 2 Effect of intercropping system on Survival of root, mortality percentage, plant height at and number of tillers of citronella

Treatment	Plant height at 60 DAS (cm)		Plant height at 120 DAS (cm)		Number of tillers at 60 DAS		Herbage yield of 1st cutting (q/ha)		Herbage yield of IInd cutting (q/ha)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Citronella sole	39.75	37.5	93.75	90.5	58.94	45.84	219.1	186.38	223.8	98.5
C:P (1:1)	36.75	35.9	86.5	84.25	55.19	43.95	107.63	95.74	111.88	53.2
C:P (2:1)	38.25	36.7	87.75	86.2	56.12	45.17	162.83	126.25	166.62	66.63
C:P (2:2)	33.75	31.9	82.75	79.5	53.38	44.4	109.14	96.2	113.13	55.99
SEm±	0.68	0.62	0.85	0.87	0.62	0.48	0.74	0.28	0.55	0.53
CD (P=0.05)	2.04	1.84	2.56	2.62	1.87	1.42	2.22	0.85	1.65	1.58

Table 3 Effect of intercropping system on growth attributes of pigeonpea in 2010-11

Treatment	Initial plant population/ m^2	Final plant population/ m^2	Plant height at 30 DAS (cm)	Plant height at 60 DAS (cm)	Plant height at 90 DAS (cm)	Plant height at maturity (cm)	Number of branches/ plant at 60 DAS	Number of branches/ plant at 90 DAS	Branches/ plant at maturity
Pigeonpea sole	7.9	7.44	38.94	114.75	143.13	162.81	6.89	13.35	16.25
C:P (1:1)	7.1	6.35	35.56	109.13	138.44	156.63	5.45	11.89	14.5
C:P (2:1)	6.78	6.1	32.31	107.75	136.75	153.88	5.25	11.1	13.65
C:P (2:2)	6.71	5.63	31.31	104.63	134.88	152.44	5.1	10.65	12.35
SEm±	0.44	0.36	0.75	1.35	1.55	1.66	0.41	0.45	0.54
CD (P=0.05)	NS	1.07	2.25	4.06	4.67	5.01	1.22	1.34	1.62

findings of Patra *et al.* (2005). The Highest herbage yield of first (219.10 q/ha in 2010-11 and 186.38 q/ha in 2011-12) and second cutting (223.80 q/ha in 2010-11and 98.50 q/ha in 2011-12) was recorded in citronella sole which was significantly superior over rest of the treatments followed by 2:1 row ratio of citronella + pigeonpea in first cutting (162.83 q/ha in 2010-11 and 126.25 q/ha in 2011-12) and 2nd cutting (166 q/ha in 2010-11and 66 q/ha in 2011-12) (Table 2). This may be due to optimum spacing available for the plants. The higher growth performance in sole crop as compared to intercropping system has also been observed by Patra *et al.* (2005). The intercrop was affected due to the presence of inter and intra-specific competition between main crop and the intercrop (pigeonpea) for growth resources such as nutrients, moisture and solar radiation due to change in crop geometry as compared to sole crop. The results of the present investigation are in close conformity with the findings of Sher *et al.* (2008).

Effect of cropping system on pigeonpea

The final plant population recorded at harvest stage significantly highest in sole stand of pigeonpea followed by 1:1 and 2:2 row ratio of citronella + pigeonpea intercropping system in 2010-11. Growth attributes (plant height and number of branches/plant) of pigeonpea were significantly influenced due to the cropping systems and highest under sole cropping at 30 DAS, 60 DAS, 90 DAS and maturity stages of crop growth (Table 3) in 2010-11. In 2011-12, the plant height of pigeonpea was significantly higher in citronella + pigeonpea intercropping (2:1) at 30 DAS, 60 DAS, 90 DAS and maturity stages of crop growth (Table 4). The highest values of growth and yield attributing characters (pods/plant and grains/pod) as well as the yields of pigeonpea were recorded under sole cropping as compared to intercropped in various combinations with citronella in 2010-11 (Table 5). However, in 2011-12, the yield attributes better under citronella + pigeonpea intercropping (2:1) (Table 5). This may be due to optimum spacing available for the plants and also fuller expression of biological N_2 fixation (BNF) with optimum space in rhizosphere as well (Sheoran *et al.* 2010). Such higher growth performance in sole crops as compared to intercropped ones has also been observed by Khapre *et al.* (1993) and Singh and Jadhav (2003). There was a general reduction in the plant population of pigeonpea and branching at later stages due to inter and intra-specific competitions under intercropping system. It might have occurred due to the presence of dominant competition between main crop and the intercrop (pigeonpea) because of vigorous growth of citronella and profuse branching and spreading nature of pigeonpea (Myaka *et al.* 2006). This could be attributed to the dissimilar conditions of plant growth and development of pigeonpea as was also evident in growth attributes (plant height, branches/plant and pods/plant). Such conditions increased the competition among plants for nutrients, soil moisture and sunlight resources (Ansari *et al*. 2012). The results of the present investigation are in close conformity with the findings of Srivastava *et al.* (2004), Marrer *et al.* (2007) and Ghosh *et al.* (2009). Cropping systems had significant effect on grain, stalk and biological yield of pigeonpea. The highest biological yield, grain yield and stover yield was recorded in pigeonpea sole which was significantly superior

Table 4 Effect of intercropping system on growth attributes of pigeonpea in 2011-12

Treatment	Initial plant population/ m^2	Final plant population/ m^2	Plant height at 30 DAS (cm)	Plant height at 60 DAS (cm)	Plant height at 90 DAS (cm)	Plant height at maturity (cm)	Number of branches/ plant at 60 DAS	Number of branches/ plant at 90 DAS	Branches/ plant at maturity
Pigeonpea sole	5.61	5.25	39.56	109.92	141.24	164	6.61	12.14	15.07
C:P (1:1)	5.72	5.35	38.89	109.31	140.37	160.75	6.96	13.07	15.1
C:P (2:1)	5.76	5.46	41.62	112.12	144.28	165.93	8.05	13.53	17.03
C:P (2:2)	5.62	5.29	38.37	108.87	139.68	160.68	6.24	11.46	14.37
SEm±	0.27	0.2	0.5	0.3	0.5	0.36	0.41	0.48	0.66
CD (P=0.05)	NS	NS	1.63	0.99	1.63	1.16	NS	NS	NS

Table 5 Effect of intercropping system on yield attributes and of pigeonpea

Treatment	Number of pods/ plant		Number of grains/ pod		1000-grain weight (g)		Biological yield (q/ha)		Grain yield (q/ha)		Stalk yield (q/ha)		Harvest index (%)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Pigeonpea sole	148.5	149.61	3.78	3.45	63.98	68.78	71.47	87.77	16.5	20.27	54.96	67.5	23.09	23.16
C:P (1:1)	142.21	152.94	3.53	2.94	63.13	70.78	35.27	49.43	8.19	10.88	27.45	38.55	23	22.07
C:P (2:1)	139.45	155.5	3.17	3.75	62.66	72.42	18.27	30.45	4.47	7.13	13.78	23.31	24.47	23.46
C:P (2:2)	135.56	152.22	2.95	3.12	62.65	66.55	36.06	46.9	8.64	10.32	27.41	36.57	23.29	22.01
SEm±	1.49	0.48	0.3	0.31	0.67	2.16	0.384	1.33	0.165	0.25	0.368	1.17	0.701	0.48
CD (P=0.05)	4.48	1.58	NS	NS	NS	2.44	1.245	4.31	0.534	0.31	1.194	3.81	NS	NS

Table 6 Effect of cropping system on Citronell oil equivalent yield, crop profitability, net returns, B: C ratio and land equivalent ratio in 2010-11 and 2011-12

Treatment	2010-11					2011-12				
	CEOY (q/ha)	Crop profitability (₹/ha/day)	Net returns (₹/ha)	B: C ratio	LER	CEOY (q/ha)	Crop profitability (₹/ha/day)	Net returns (₹/ha)	B: C ratio	LER
Citronella sole	354.26	837	272.04	9.4	1	322.3	753.4	244.88	8.42	1
Pigeonpea sole	75.72	187.6	52.92	4.8	1	76.3	200.7	56.62	5.2	1
C:P (1:1)	213.2	497.6	161.74	8.4	0.99	168.2	485.1	157.67	8.24	1.05
C:P (2:1)	284.09	687.9	223.57	9.8	1.01	235.3	613	199.22	8.75	1.08
C:P (2:2)	217.49	770.4	250.39	12.6	1.03	172	487.9	158.57	8.01	1.03
SEm±	2.25					2.2				
CD (P=0.05)	6.84					6.6				

to all other treatment in both years of experimentation. The harvest index has been recorded non-significant difference. Similar observations were also made by Srivastava *et al.* (2004) and Ansari *et al.* (2014). Citronella + pigeonpea (2:2) intercropping system fetched higher net returns as well as B: C ratio over sole and other combinations due to more combined yield. This might be due to beneficial effect of intercropping system which resulted more in pigeonpea equivalent yield as compared to either of the sole crops and combinations. Similar results were reported by Sharma *et al.* (2010).

Effect of cropping system on soil fertility status

Diverse citronella – pulses intercropping system affected the fertility status of soil. The pH, soil EC and bulk density was reduce 5, 11.5 and 8.5% respectively in pigeonpea sole cropping followed by citronella + pigeonpea (1:1) intercropping than citronella sole cropping (Table 1). However, the organic carbon, available N (kg/ha), available P_2O_5 (kg/ha), available K_2O (kg/ha) increased by 8.5, 9.8, 12.5 and 4.8% respectively in pigeonpea sole cropping than citronella sole cropping (Table 1).

Effect of cropping system on system productivity and economics

Citronella sole cropping system fetched higher net returns as well as B: C ratio over intercrops. Among intercropping system, citronella + pigeonpea intercropping system gave higher economic profit. This might be due to beneficial effect of intercropping system which resulted more in pigeonpea equivalent yield as compared to either of the sole crops and combinations. Intercropping systems showed improvement in citronella equivalent oil yield (CEOY) (Table 6), net returns and B: C ratio (Table 6). The citronella sole cropping system gave significantly the highest citronella equivalent oil yield, net returns and B: C ratio followed by citronella + pigeonpea (2:1) and citronella + pigeonpea (2:2) intercropping system than other cropping systems (Fig 2). Citronella sole system on an average fetched ₹ 272.04×10^3 in 2010-11 and ₹ 244.88×10^3 in 2011-12 followed by citronella: pigeonpea (2:2) (₹ 250.4×10^3) in 2010-11 and citronella: pigeonpea (2:1) (₹ 199.22×10^3) net returns (Table 6). The higher B: C ratio was recorded under citronella: pigeonpea (2:2) (12.6) in 2010-11 and citronella: pigeonpea (2:1) (8.75) in 2011-12 than other cropping systems. The results are in accordance with the findings of Saikia *et al.* (2006). Similar results were reported by Sharma *et al.* (2010). It was due to similar citronella oil yield under intercropping system as that of its sole stand, and additional yield of pigeonpea as a bonus in intercropping system. The results are in accordance with the findings of Saikia *et al.* (2006).

Effect of cropping system on land equivalent ratio and crop profitability

The LER value in intercropping system indicated yield advantage over sole stand due to better land utilization. The higher LER values in intercropping, i.e.1.03 to 1.08 clearly indicate 3 to 8% advantage over their sole stand (Table 6). The results are in accordance with the Ghosh *et al.* (2009). Citronella sole recorded the highest crop profitability (Table 6). This could be attributed to higher productivity of crops. The results are conformity with (Ghosh *et al.* 2009).

CONCLUSION

Thus results of the present investigation clearly demonstrate that citronella sole cropping followed by pigeonpea + citronella intercropping system (2:1) can be practiced to achieve better high yield as well as profitability than other cropping system in sandy loam soils of north and central India.

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