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EVALUATION OF VARIOUS KODON MILLET (*PASPALUM SCROBICULATUM* L.) AND PIGEONPEA (*CAJANUS CAJAN* L. MILLSP.) INTERCROPPING SYSTEMS ON PRODUCTIVITY AND SOIL PROPERTIES UNDER RAINFED CONDITIONS

D. K. TIWARI*[1], H. S. KUSHWAHA[2], R. S. SHARMA[3] AND M. L. KEWAT[4]
[1]JNKVV, ZARS, Chhindwara (MP),
[2]Department of NRM, MGCGVV, Chitrakoot, Satna (MP), INDIA
[3]Department of Agronomy, JNKVV, Jabalpur (MP), INDIA
[4]Department of Agronomy, JNKVV, Jabalpur (MP), INDIA
Zonal Agricultural Research Station, JNKVV, Chhindwara - 482 004 (M P), INDIA
e-mail: tiwaridk78@gmail.com

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***Corresponding author**

ABSTRACT
A field experiment was conducted during *Kharif* season for two consecutive years (2007-08 and 2008-09) at Dindori, Madhya Pradesh to evaluate the kodon millet and Pigeonpea intercropping systems on productivity, soil properties and economics under rainfed conditions. It is obvious from the data that growing of short duration kodon millet cv DPS-19 with medium duration spreading type pigeonpea cv No. 148 in 2:1 rows, found to be best intercropping system with regard to kodon equivalent yield (4151 kg/ha), land equivalent ratio (1.60), maximum gross monetary returns (Rs. 33316/ha), net monetary returns (Rs. 18124/ha) and benefit-cost ratio (2.19) and proved significantly superior over other intercropping systems as well as sole cropping of either crops. Data on changes in soil properties at the end of two consecutive crop-cycles over their parental status indicated that there was no adverse effect of any cropping systems on the soil properties. However, some beneficial effects regarding improvement in nitrogen content has been observed during second year under sole cropping of pigeonpea or in association with kodon millet (short duration kodon millet with short to medium duration spreading type Pigeonpea in 2:1 rows).

INTRODUCTION

Kodon millet is one of the most popular food grain crops grown in almost all tribal belts of the state having poor resource base with the farmers. It is extensively grown under both as a sole and mixed cropping system through broadcast method of sowing. In rainfed conditions it is mostly grown in association with pigeonpea as mixed cropping for minimizing agricultural risks, maximizing productivity and profit besides fulfillment of the domestic needs (grain and pulse) of the growers and improving quality of natural resources particularly soil fertility (Dhandayuthapani *et al.*, 2015). However, by slight modification in the cropping systems from mixed cropping to intercropping system it could be made advantageous and easily acceptable for the farmers due to ease in agricultural operations if crops are sown in line. Under intercropping situations, the crop components with variable genotypic behaviors cause their identical effect on growth of component crops due to change in micro environment for competition (Trenbath, 1974; Willey, 1979).

Kodon millet, in general, sown in closer row spacing (20 cm), while pigeonpea is sown in wide row spacing of 60 to 75 cm depending on the duration and growth habit of the varieties. Mostly kodon millet matures earlier (less than 120 days) than pigeonpea (120 to 200 days). Therefore, it could be possible to accommodate desired rows of pigeonpea by replacing some rows of kodon millet. Moreover, kodon millet with good harvest index can complete its life cycle before harvest of pigeonpea. Henceforth, pigeonpea as an intercrop with kodon millet may be a successful intercropping system. The varieties having heterogenous growth habits and maturity of varying durations are available for both kodon millet and pigeonpea (Holker *et al.,* 1991). Several workers have identified many successful intercropping systems under additive series by considering pigeonpea as main crop (Dubey *et al.*, 1991 and Singh *et al.*, 1991), while others have found the success of replacement series of intercropping by considering pigeonpea as an intercrop (Maurya and Rathi, 2000). Since the information of suitable intercropping systems of varying duration kodon varieties with Pigeonpea having different maturity and growth habit is meager in the literature. Therefore, the identification of suitable varieties of both crop components is imperative to minimize the competition for available resources and maximize the complementary effects of kodon millet and pigeonpea varieties under intercropping system.

MATERIALS AND METHODS

The present investigation was conducted on the Research Farm of Regional Agricultural Research Station, Dindori (MP) during *Kharif* season for two consecutive years (2007-08 and 2008-09), with the objectives to judge suitable kodon millet and Pigeonpea intercropping system to maximize the productivity and monetary returns per unit area of land and per unit time with the efficient use of land and resources, besides the improvement in the soil-health.

The soils of the experimental field are skeletal in texture. The soil-depth was 45 cm in the experimental field. The soil of the field was neutral in reaction (pH 6.28), low in organic carbon content (0.3%) and analyzing low in available N (163.0 kg/ha) estimated by alkaline permanganate method (Subbiah and Asija 1956), available P (7.0 kg/ha) estimated by Olson's method (Olson *et al.*, 1954) and high in available K (263.0 kg/ha) as determined by flame photometer method (Hanway and Heidal, 1952) before conduction of present investigation.

The field experiment consisted of fourteen treatments i.e. 2 sole croppings of kodon millet varieties (T_1 – long duration cv IPS-147 and T_2 – short duration cv DPS-19), 4 sole croppings of pigeonpea varieties (T_3- medium duration spreading type cv No. 148, T_4 – medium duration erect type cv JKM-7, T_5 – short duration spreading type cv ICPL-87 and T6 – short duration erect type cv UPAS-120) and 8 possible intercropping systems (T_7 – long duration kodon millet cv IPS-147 + medium duration spreading type pigeonpea cv No. 148, T_8 – short duration kodon millet cv DPS-19 and medium duration spreading type pigeonpea cv No. 148, T_9 – long duration kodon millet cv IPS-147 and medium duration erect type pigeonpea cv JKM-7, T_{10} – short duration kodon millet cv DPS-19 and medium duration erect type pigeonpea cv JKM-7, T_{11} – long duration kodon millet cv IPS-147 and short duration spreading type pigeonpea cv ICPL-87, T_{12} – short duration kodon millet cv DPS-19 and short duration spreading type pigeonpea cv ICPL-87, T_{13} – long duration kodon millet cv IPS-147 and short duration erect type pigeonpea cv UPAS-120 and T_{14} – short duration kodon millet cv DPS-19 and short duration erect type pigeonpea cv UPAS-120), were carried out in randomized block design with three replications.

Sowing of varieties of both crops (as per treatments) was done on July 5 during both years of investigation. The gross plot size of each treatment was 10.00 m x 5.40 m. The row to row distance was 20 cm and 60 cm apart for sole cropping of kodon millet and pigeonpea, respectively. The sowing of kodon millet and pigeonpea was done in 2:1 row proportion at 20 cm apart in plots receiving intercropping systems. The fertilizer dose was 40 kg N + 20 kg P_2O_5 + 10 kg K_2O/ha and 20 kg N + 40 kg P_2O_5 + 10 kg K_2O/ha for kodon millet and pigeonpea, respectively. The fertility dose for intercropping treatments was as per proportionate area of crop components. Both crops were grown as per recommended package of practices of their cultivation.

The observations were recorded on yield attributes, kodon equivalent yield (KEY) as suggested by Waghmare and Singh, (1982). The yield of pigeonpea was converted into kodon equivalent yields (KEY) on the basis of existing market value of the crops. Finally, the combined yield (total productivity) was worked out treatmentwise by adding kodon millet equivalence with kodon millet yield in intercropped stands. LER of the system was calculated by using the formula given by Willey (1979). The gross monetary return (GMR) per hectare under each treatment was determined by substracting the cost of cultivation of respective treatments.

The Monetary advantages of kodon millet + pigeonpea intercroppings based on LER values were also calculated by using the following formula as suggested by Willey (1979).

$$\text{Monetary advantage based on LER} \quad (\text{Value of combined yield}) \quad \frac{\text{LER} \quad 1}{\text{LER}}$$

Benefit-cost ratio of the treatments was worked out on the basis of two years pooled data of the produce obtained from two years of field experimentation. Data recorded on different parameters pertaining to kodon millet + pigeonpea crop was tabulated and analysed statistically by the method of analysis of variance as suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Yield of component crops

The mean data averaged over replications showed that grain and straw yields of both kodon and pigeonpea varieties were significantly higher under sole cropping to that of under intercropping systems mainly due to no reduction in plant population of varieties of both the crops in question. However, yields of both kodon varieties were significantly reduced under intercropping systems due to reduction in one third population of kodon millet for accommodating pigeonpea as an intercrop in every third regular row, which attributed to less grain and straw yields of kodon millet under intercropped stands. The rate of reduction in yields of kodon millet varieties under intercropped stand over pure stand was greater in case of IPS-147 than DPS-19. The growth of kodon millet cv IPS-147 depressed much due to competition for light between long statured pigeonpea as an intercrop and long growing period of IPS-147. Short duration kodon millet cv DPS-19 had completed its active growth phase before facing the shading effects from tall pigeonpea at advanced growth stage. This appears to be the probable reason for lesser reduction in grain and straw yields of DPS-19 than IPS-147 under intercropped stands over their sole stand. These results are in close conformity with the findings of Dubey *et al.,* (1991), Dubey and Shrivas (1997) and Ramamoorthy *et al.,* (2004).

Medium duration spreading type pigeonpea cv No. 148 (955 kg/ha) outyielded among all the 4 varieties in sole stand followed by JKM-7 (857 kg/ha), ICPL-87 (855 kg/ha) and UPAS-120 (789 kg/ha), but variation between JKM-7 and ICPL-87 was found to be non significant. Profuse branching, more filled pods/plant could be assigned the reasons for higher yield under former variety to that of other varieties. Reduction in seed yields under intercropped stands compared to sole cropping was maximum with long duration erect type cv JKM-7 among all pigeonpea varieties due to poor branching coupled with less pods/plant. These results are in close conformity with the findings of Dubey *et al.* (1991) and Ramamoorthy *et al.* (2004).

Kodon equivalent yield (KEY)

Table 1: Yield of Kodon millet and Pigeonpea, Kodon equivalent yields, LER, GMR, NMR and B:C ratio as influenced by of kodon millet and pigeonpea intercropping systems (Pooled data of two years)

Treatment	Kodon Millets yield (kg/ha)		Pigeonpea yields (kg/ha)		Kodon equivalent yields (kg/ha)	LER	GMR (Rs./ha)	NMR (Rs./ha)	B:C ratio
	Grain	Straw	Seed	Stick					
T_1	1727	3910	-	-	1727	1.00	15999	6299	1.65
T_2	1818	4108	-	-	1818	1.00	16834	7134	1.74
T_3	-	-	955	2498	3407	1.00	25098	12711	2.03
T_4	-	-	857	2328	3059	1.00	22580	10193	1.82
T_5	-	-	855	2319	3050	1.00	22509	10122	1.82
T_6	-	-	789	2091	2817	1.00	20763	8376	1.68
T_7	1142	2565	744	2008	3797	1.44	30147	14955	1.98
T_8	1468	3245	752	2021	4151	1.60	33316	18124	2.19
T_9	1038	2270	627	1747	3275	1.33	26070	10878	1.72
T_{10}	1392	3084	636	1790	3661	1.51	29608	14416	1.95
T_{11}	1025	2268	664	1875	3395	1.37	26970	11778	1.78
T_{12}	1374	2981	675	1913	3783	1.55	30415	15223	2.00
T_{13}	1015	2253	613	1725	3201	1.36	25523	10331	1.68
T_{14}	1364	3070	619	1795	3571	1.53	28964	13772	1.91
SEm±	61	73	49	67	113	NA	623	409	NA
CD(p=0.05)	181	217	146	201	336	-	1857	1218	-

Table 2: Available nitrogen, phosphorus and potassium in the soil before sowing and after harvesting of crops under various intercropping systems (during 2007-08 and 2008-09)

Treatment	Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	2007		2008	2007		2008	2007		2008
	PS	PH	PH	PS	PH	PH	PS	PH	PH
T_1 - Sole crop of long duration kodon millet cv. IPS 147	161	154	156	7.4	7.2	7.0	258	268	257
T_2 - Sole crop of short duration kodon millet cv. DPS 19	165	157	153	7.0	7.1	6.9	261	270	260
T_3 - Sole crop of pigeonpea medium duration spreading type cv. No. – 148	161	165	170	6.9	7.0	6.7	267	262	261
T_4 - Sole crop of pigeonpea medium duration erect type cv. JKM – 7	164	160	168	7.3	6.8	6.8	260	270	259
T_5 - Sole crop of pigeonpea short duration spreading type cv. ICPL – 87	159	166	167	7.1	6.9	7.0	266	264	263
T_6 - Sole crop of pigeonpea short duration erect type cv. UPAS – 120	163	163	169	7.3	7.1	6.9	259	261	258
T_7 - Kodon millet long duration + pigeonpea medium duration spreading type (2 : 1 rows)	163	168	166	6.9	6.7	6.8	265	263	255
T_8 - Kodon millet short duration + pigeonpea medium duration spreading type (2 : 1 rows)	167	165	170	7.0	7.0	6.7	261	260	258
T_9 - Kodon millet long duration + pigeonpea medium duration erect type (2 : 1 rows)	162	167	168	7.1	7.1	6.8	261	259	260
T_{10} - Kodon millet short duration + pigeonpea medium duration erect type (2 : 1 rows)	158	165	165	7.5	6.9	6.9	268	266	257
T_{11} - Kodon millet long duration + pigeonpea short duration spreading type (2 : 1 rows)	160	168	167	7.3	6.7	6.8	265	263	258
T_{12} - Kodon millet short duration + pigeonpea short duration spreading type (2 : 1 rows)	165	165	171	7.2	7.2	7.0	262	260	260
T_{13} - Kodon millet long duration + pigeonpea short duration erect type (2 : 1 rows)	162	166	168	7.0	7.0	6.9	267	261	255
T_{14} - Kodon millet short duration + pigeonpea short duration erect type (2 : 1 rows)	163	164	167	7.3	7.1	7.0	265	263	256
SEm±	3.2	3.1	2.9	0.37	0.47	0.41	4.1	4.4	4.
CD at 5%	NS	9.3	8.6	NS	NS	NS	NS	NS	NS

PS = Pre-sowing ; PH = Post-harvest

KEY values determined for different treatments, showed that sole cropping of kodon millet gave the lowest yield The KEY significantly increased under all kodon millet + pigeonpea intercropping systems (Table 1). The KEY was remarkably maximum (4151 kg/ha) with short duration kodon millet cv DPS 19 with medium duration spreading type pigeonpea cv No. 148 intercropping system, followed by long duration kodon millet cv IPS 147 with medium spreading type pigeonpea cv No. 148 (3797 kg/ha) and short duration kodon millet cv DPS 19 with short duration spreading type pigeonpea cv ICPL-87 (3783 kg/ha) and proved statistically superior over remaining kodon millet + pigeonpea intercropping systems which attained the KEY ranging from 3201 to 3395 kg/ha, being lesser than above mentioned intercropping systems. The proper varietal adjustment for zero competition (for nutrients, moisture, light and space) due to variation in maturity, growth habits and better yielding ability of varieties of crop components might be the reason for the success of aforesaid intercropping systems. Several workers have also corroborated the similar findings from their studies on varietal adjustments of crop components under different intercropping systems (Billore and Joshi, 2004; Mandal *et al*., 2014).

Land equivalent ratio (LER)

It is obvious from the LER values that all kodon millet + pigeonpea intercropping systems led to register significantly higher LER values than sole cropping of both kodon millet and pigeonpea (Table 1). Intercropping of short duration kodon millet cv DPS-19 with medium duration spreading type pigeonpea cv No. 148 in 2:1 rows at 20 cm apart, led to record maximum LER (1.60) followed by short duration kodon millet cv DPS-19 with short duration spreading type pigeonpea cv ICPL-87 (1.55), and short duration kodon millet cv DPS-19 with short duration erect type pigeonpea cv UPAS-120 (1.53) compared to other combinations of kodon millet and pigeonpea intercropping systems. Better synergy coupled with zero competition due to variation in maturity, growth habits and mismatch in active growth stages caused excellent

utilization of growth resources. As a consequence, the yield advantage under former intercropping systems was more (60, 55 and 53 % respectively) to that of other intercropping systems. The results are in close conformity with the finding of several other workers also Billore and Joshi, 2004.

Economics of intercropping systems

Gross monetary returns, net monetary returns and benefit-cost ratio varied due to intercropping systems (Table 1). The values of above economic indices were minimum under sole copping of late maturity kodon millet cv. IPS-147, which slightly increased with sole cropping of early maturity cv. DPS-19 as harvesting coincided with recession of rains and gave higher grain yield as it did not face any moisture stress during grain filling stage. But reverse was true in case of late maturing cv. IPS-147. Similarly, sole cropping of medium duration spreading type variety cv. No. 148 recorded higher values of economic indices due to higher seed and stick yield compared to other varieties. The economic indices attained the maximum values (Rs. 33316/ha GMR, Rs. 18124/ha NMR and 1.60 B: C ratio) when short duration kodon millet cv. DPS-19 was intercropped (in 2:1 row proportion) with medium duration pigeonpea cv. No. 148 followed by short duration spreading pigeonpea cultivar ICPL-87 being at par to sole cropping of pigeonpea cv. No. 148 in case of benefit-cost ratio only. More grain/seed and straw/stick yields under latter intercropping and sole cropping system could be assigned the reason for higher economics returns relative to other sole and intercropping systems. These results are in close conformity with the findings of Dubey and shrives (1997), Vyas *et al.,* (2006); and Sharma *et al.*, (2008).

Changes in available NPK

It is evident from the results (Table 2) that available P and K contents of the soil did not vary due to different intercropping systems including sole cropping of either crops at the end of each crop cycle over their initial status But available N in soil showed significant increase at the end of each crop cycle in each plot having cultivation of pigeonpea either as sole crop or as an intercrop with kodon millet. These results were more pronounced during the second year (2008-09) of investigation than those recorded during the first year (Table 2). Better growth of pigeonpea crop in both years of experimentation had added more organic matter due to shading of more leaves at maturity stage, which led to increase residual N in the soil. Several workers have also underlined in their studies that plant residues and root nodules of legume crops help to release N after decomposition and also increase the residual N content in the soil (Das and Mathur, 1980, Gangwar and Kalra, 1981, Sharma and Choubey, 1991 and Prasanna Kumar, 2005).

There was not much deviation in P and K contents of soil at the end of crop cycle every year over their previous status due to different cropping systems. Adequate quantity of P and K were applied to the crops grown under different treatments, which were exhausted from the soil by the crop components. Legume crops also have ability to utilize these nutrients more effectively (Van Schreven, 1958). Therefore, P and K contents were not improved and even shown a declining trend over their initial status and reduction of P and K contents was prominent with the completion of 2 crop cycles only under the treatments associated with the cultivation of pigeonpea either alone or in association with kodon millet. Similar results have been also reported under different legume based intercropping systems in different agro-climatic conditions (Sharma and Choubey, 1991, Balpande *et al*., 1994; and Prasanna Kumar, 2005).

It is concluded that intercropping of early kodon millet cv. DPS-19 with medium duration pigeonpea cv. No. 148 was found more remunerative under rainfed conditions of Northern hill of Chhattisgarh besides increasing the residual N in the soil.

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