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Performance of pigeonpea (*Cajanus cajan*) + greengram (*Phaseolus radiatus*) intercropping system as influenced by moisture-conservation practice and fertility level under rainfed conditions

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ABSTRACT

A field experiment was conducted on moisture conservation and nutrient-management practices in pigeonpea [*Cajanus cajan* (L.) Millsp.]-greengram [(*Phaseolus radiatus* (L.) Wilczek] intercropping system under rainfed conditions on sandy-loam soil at New Delhi in rainy season 2004 and 2005. The planting of one row of greengram between paired rows (30.70 cm) of pigeonpea proved superior to the sole pigeonpea in terms of pigeonpea-equivalent yield, water use and economics. Application of soil mulch + farmyard manure 5 tonnes/ha + Kaolin 6 per cent spray was found the best moisture-conservation practice by recording the maximum values of pigeonpea-equivalent yield, nutrient uptake and water-use efficiency. Application of 40 kg P_2O_5/ha + 25 kg S / ha + phosphate-sutibilizing bacteria (PSB) recorded the maximum values of pigeonpea-equivalent yield, nutrient uptake, water-use efficiency and net returns.

Key words : Economcis, Intercropping, Fertility level, Mulch, Nutrient uptake, Pigeonpea, Water-use efficiency

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is the most important rainy-season (*kharif*) grain legume in India, grown predominantly under rainfed conditions. It occupies 27 per cent of total pulse area but accounts for only 17 per cent of gross pulse production in the country, Limited and erratic rainfall in the rainfed areas makes pigeonpea vulnerable to experience moisture-stress conditions during the later part of its growth, resulting in severe yield reduction.

Adequate soil moisture is the key to successful crop production in dryland areas. The major source of soil-moisture loss is evapo-transpiration. Use of organic manure as well as mid-season corrections through mulches, antitranspirants and planting methods are effective in increasing the productivity and water use by pigeonpea under rainfed conditions. Like other field crops, pigeonpea also requires essential elements nitrogen, phosphorus and potassium for balanced nutrition. With the intensification of agriculture, the traditional boundaries between primary and secondary nutrients are becoming narrower. Crops require as much sulphur as they do phosphorus. To improve and stabilize the productivity of pigeonpea under these adverse situations, intercropping with short-duration legumes like greengram [*Phaseolus radiatus* (L.) Wilczek] has been recommended (Ahlawat *et al.*, 1986).

A good deal of research work has been done on the nutrient management and moisture-conservation practices. Yet there exists a lacuna in assessing their favourable effect as well as their interaction in pigeonpea-greengram intercropping system under rainfed conditions. Therefore it was deemed desirable to investigate the role of intercropping systems along with moisture-conservation practice and nutrient management in rainfed pigeonpea.

MATERIALS AND METHODS

The field experiment was conducted on a sandy-loam soil at the research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi in two consecutive rainy (*kharif*) seasons (2004 and 2005). This location has a typical semi-arid and subtropical climate, characterized by hot dry summer and cool winter. The rainfall received during the growing period from July to December was 483 mm in 2004 and 577.5 mm in 2005. The experiment was laid out in split-plot design with three replications. The treatment combinations cormpised two cropping systems [pigeonpea sole (50 cm row spacing) and pigeonpea paired row (30/70 cm row spacing) + one row of greengram]; and three moisture-conservation practices (soil mulch, soil mulch + farmyard manure @ 5 tonnes and soil mulch + FYM @ 5 tonnes/ha + Kaolin 6 per cent spray) in main plots; and four fertility levels (the control, 40 kg P_2O_5/ha, 40 kg P_2O_5/ha + 25 kg S/ha and 40 kg P_2O_5/ha + 25 kg S/ha +phosphate-solubilizing bacteria (PSB) in subplots. The gross and net plot sizes were 12 m^2 and 8 m^2 respectively.

Fertilizers were drilled in bands 8-10 cm below the surface. The full dose of phosphorus and sulphur as per treatment through single superphosphate and gypsum respectively was applied just before sowing the crops. The placement was done through an iron pipe (*pora*) attached to the bullock-drawn country plough. Farmyard manure was incorporated in the plots after preparing the lay-out as per treatments in both the years. 'Pusa 991' and 'Pusa Ratna' varieties of pigeonpea and greengram respectively were used for experimental purpose. The crop was sown on 8 July 2004 and 1 July 2005. The pigeonpea seeds were sown @ 15 kg/ha by *kera* (dropping the seeds in furrow behind the plough). The seed rate of greengram was decided according to the space available for intercropping in pigeonpea. The spacing between row to row in sole pigeonpea was maintained at 50 cm, whereas paired row sowing was done at a distance of 30 cm, keeping the distance between two pairs of rows 70 cm. One row of greengram was sown between two paired rows of pigeonpea. The first soil mulch was created at 25 days after sowing (DAS) and second at 40 DAS in both the years. Kaolin (6 per cent suspension) was sprayed as per treatment over the crop foliage at 80 DAS in both the years. Greengram and pigeonpea were harvested respectively on 20 September and 5 December 2004 and on 15 September and 29 November 2005.

RESULTS AND DISCUSSION

Yield

The cropping system had no effect on grain and stalk yields of pigeonpea (Table 2). This could be attributed to the existence of similar conditions of plant growth and development of pigeonpea, as was also evident in growth attributes. Kantwa *et al.* (2005) also made similar observations.

The grain and stalk yields of pigeonpea were significantly influenced by moisture-conservation practices during both the years. The highest grain yield (15.72 and 17.75 q/ha) was recorded with the application of soil mulch + FYM 5 tonnes/ha + Kaolin 6 per cent spray, which was 12.4 and 11.5 per cent higher than with soil mulch during 2004 and 2005 respectively. This could be ascribed to the combined effect of these components in more effectively reducing the evapo-transpiration losses and increasing the water-holding capacity of the soil. Soil mulch reduces the evaporation losses, FYM increases the water-holding capacity of the soil and Kaolin spray reduces the transpiration losses. Jat and Gautam (2001) reported similar results in pearlmillet.

Fertility level significantly affected the grain and stalk yields in both the years. Maximum grain yield was obtained with the application of 40 kg P_2O_5 + 25 kg S/ha + PSB (16.96 and 19.03 q/ha), followed by 40 kg P_2O_5 + 25 kg S/ha (16.40 and 18.29 q/ha), which was 37.1, 33.0 and 32.6, 27.8 per cent higher over the control during 2004 and 2005 respectively. The increase in grain and stalk yields of pigeonpea on application of phosphorus and sulphur was largely a function of improved growth, translocation of more photosynthates towards sink and consequent development of yield attributes. These results are in conformity with those of Kantwa *et al.* (2005).

Nutrient uptake

The cropping system had no marked influence on P and S uptake by grain as well as stalk of pigeonpea, but the total uptake of P and S was significantly higher with sole pigeonpea than with pigeonpea+greengram intercropping system (Table 1). This might be due to the compound effect of grain and stalk yield. Kantwa *et al.* (2005) reported similar results.

The moisture-conservation practices significantly influenced the P and S uptake by grain and stalk as well as total uptake of pigeonpea (Table 1). The maximum uptake of P and S was recorded under soil mulch + FYM @ 5 tonnes/ha + kaolin 6 per cent spray, which was on a par with soil mulch + FYM @ 5 tonnes/ha. The increased uptake of P and S under these treatments could be attributed to the higher grain and stalk yields, apparently because of increased availability of water to the plants. Adequate supply of moisture in general is known to improve the growth and dry-matter production of crop directly as well as indirectly by increasing the availability and utilization of nutrients. Yadav (2000) also reported similar results.

Fertility levels significantly improved the the uptake of P and S in pigeonpea compared with the control (Table 1). Application of 40 kg P_2O_5+25 kg S/ha + PSB, being on a par with 40 kg P_2O_5 + 25 kg S/ha, recorded significantly higher uptake of P and S compared with the control and 40 kg P_2O_5/ha. This could be attributed to the fact that added phosphorus and sulphur increased the P and S content in the grain and stalk by providing balanced nutritional environment inside the plant and higher photosynthetic efficiency, which in turn might have resulted in profused shoot and root growth, and thereby activating greater absorption of P and S from the soil, finally leading to improved grain and stalk yields.

Since the uptake of nutrient is a function of dry matter and nutrients, the increased grain and stalk yields together

Table 1. Effect of cropping system, moisture-conservation practice and fertility level on yield attributes and yield as well as nutrient uptake by pigeonpea (pooled data of 2 years)

Treatment	No. of pods/plant	No. of grains/ pod	1,000-grain weight (g)	Yield (q/ha)		Pigeonpea-equivalent yield (q/ha)	Total nutrient uptake (kg/ha)	
				Pigeonpea	Greengram		Phosphorus	Sulphur
Cropping system								
Pigeonpea sole (50 cm)	164.58	3.60	74.68	16.28		16.28	11.86	13.47
Pigeonpea paired row (30/70 cm) + one row of greengram	158.40	3.53	73.66	15.78	2.60	18.25	11.32	12.83
CD (P=0.05)	NS	NS	NS	NS		NS	0.46	0.52
Moisture-conservation practice								
Soil mulch	154.16	3.39	72.50	14.96	2.09	16.00	10.81	12.29
Soil mulch + FYM 5 t/ha	164.06	3.62	74.81	16.40	2.56	17.69	11.84	13.43
Soil mulch + FYM 5 t/ha + kaolin 6%	166.26	3.68	75.19	16.74	2.70	18.09	12.13	13.73
CD (P=0.05)	7.92	0.20	NS	1.01	0.31	1.00	0.58	0.71
Fertility level								
Control	144.30	3.00	70.57	13.34	1.74	14.22	9.20	9.88
40 kg P_2O_5/ha	158.29	3.50	73.51	15.44	2.29	16.59	11.02	12.22
40 kg P_2O_5/ha + S 25 kg/ha	170.11	3.83	75.79	17.34	2.76	18.74	12.77	14.91
40 kg P_2O_5/ha + S 25 kg/ha + PSB	173.25	3.93	76.81	18.00	3.00	19.51	13.36	15.61
CD (P=0.05)	11.03	0.24	NS	1.16	0.33	1.17	0.75	0.86

with higher P and S content resulted in greater uptake of these elements. The increased nutrient content and their uptake with phosphorus and sulphur support the findings of Jat and (2001).

Pigeonpea-equivalent yield (PEY)

The cropping system showed measurable improvement in PEY in both the years (Table 2). Pigeonpea intercropped with greengram recorded significantly higher PEY than sole pigeonpea. The higher PEY in intercropping treatment was due to similar yield of pigeonpea to that of its sole stand, and an additional yield of greengram as a bonus in intercropping system.

Various moisture-conservation practices showed remarkable improvement in PEY in both the years (Table 2). Soil mulch + FYM @ 5 tonnes/ha + kaolin 6 per cent spray, being on a par with soil mulch + FYM @ 5 tonnes/ ha, recorded maximum PEY and while it was minimum under soil mulch. It might be because significant increase in grain yield of pigeonpea along with increased yield of greengram in these treatments over soil mulch resulted in higher pigeonpea-eqivalent yield.

The fertility levels greatly improved the PEY in both the years. Application of 40 kg P_2O_5 + 25 kg S/ha + PSB recorded significantly higher PEY than the control and 40 kg P_2O_5/ha, which was on a par with that of 40 kg P_2O_5 + 25 kg S/ha (Table 2). This might be attributed to increase in economic yield of both the component crops with phosphorus and sulphur application. The contributing effect of various yield attributes and yield fetched the maximum PEY at different fertility levels.

Soil-moisture study

Water-use efficiency in terms of pigeonpea-equivalent yield showed marked variation due to cropping system (Table 3). Pigeonpea paired row + one row of greengram system recorded higher water-use efficiency than sole pigeonpea. This might be because the grain yield of both the crops was proportionately higher than the amount of water used for biomass production. Pigeonpea intercropped with greengram utilized more water for evapotranspiration and metabolic activities. Rate of moisture use was higher in pigeonpea + greengram intercropping system than pigeonpea sole (Table 2). It could be attributed to the fact that both the crops absorbed more moisture for dry-matter production than sole pigeonpea, which resulted in higher rate of moisture use in pigeonpea + greengram intercropping system than in sole pigeonpea. In general, the crops extracted greater amount of soil moisture from the top 0-30 cm soil layer than from 30-60 and 60-90 cm soil depths in both the systems (Table 3). It might be due to greater availability of soil moisture in this soil layer, and

Table 2. Effect of cropping system, moisture-conservation practice and fertility level on consumptive use, water-use efficiency (WUE), rate of moisture use, moisture-extraction pattern and economics (average data of 2 years)

Treatment	Consumptive use (mm)	WUE (kg/ha–mm)	Rate of moisture use (mm/day)	Moisture-extraction pattern (%) 0-30 cm	30-60 cm	60-90 cm	Net returns (Rs/ha)	B:C ratio
Cropping system								
Pigeonpea sole (50 cm)	349.15	4.83	2.28	51.37	28.08	20.55	16,406	1.63
Pigeonpea paired row (30/70 cm) + one row of greengram	368.35	5.12	2.40	49.98	28.54	21.49	19,202	1.81
Moisture-conservation practice								
Soil mulch	345.73	4.79	2.26	51.18	28.12	20.00	16,854	1.81
Soil mulch + FYM 5 t/ha	364.13	5.02	2.38	50.46	28.38	21.17	18,536	1.79
Soil mulch + FYM 5 t/ha + kaolin 6%	366.40	5.10	2.39	50.38	28.44	21.19	18,023	1.56
Fertility level								
Control	334.80	4.39	2.18	51.07	28.11	20.82	14,056	1.55
40 kg P_2O_5/ha	357.50	4.79	2.33	50.75	28.23	21.03	16,664	1.61
40 kg P_2O_5/ha + S 25 kg/ha	369.00	5.26	2.41	50.48	28.44	21.09	19,628	1.80
40 kgP_2O_5/ha + S 25 kg/ha + PSB	373.70	5.39	2.44	50.39	28.48	21.13	20,870	1.92

the existene of maximum root biomass in this soil profile, which resulted in maximum extraction of soil moisture from this profile. Moisture depletion from deeper layers by pigeonpea + greengram intercropping system might be due to moisture stress in the upper 0-30 cm soil profile, compelling the roots to go deeper in search of moisture. It explains the reason behind greater depletion of soil moisture from deeper soil profiles. Deka and Pal (1993) reported similar observation.

Water-use efficiency in terms of pigeonpea-equivlaent yield, consumptive use and rate of moisture use increased appreciably due to moisture-conservation practices (Table 3). The highest value of all these three moisture characteristics on an average was associated with soil mulch + FYM @ 5 tonnes/ha + Kaolin 6 per cent spray, and the lowest with soil mulch. The increase in moisture characteristics due to moisture-conservation practices could be attributed to vigorous crop growth resulting from increased availability of soil moisture. Das and Gautam (2003) reported similar results in pearl millet. Moisture-conservation practices brought about marked influence on the moisture-extraction patterns of the crops. Maximum soil-moisture extraction from 0-30 cm soil layer was registered under soil mulch and the lowest under soil mulch + FYM @ 5 tonnes/ha + Kaolin 6 per cent spray. This might have resulted due to slow canopy development, which caused the surface to be exposed to solar radiation, leading to higher evaporation. However, the reverse was true for 30-60 and 60-90 cm soil layers, where the maximum percentage of moisture was depleted under soil mulch + FYM @ 5 tonnes/ha + kaolin 6 per cent, followed by soil mulch + FYM @ 5 tonnes/ha.

Fertility levels increased the consumptive use, water-use efficiency and rate of moisture use compared with the control (Table 3). The highest water-use efficiency was recorded with 40 kg P_2O_5 + 25 kg S/ha + PSB, followed by 40 kg P_2O_5 + 25 kg S/ha and 40 kg P_2O_5/ha, and lowest with the control. It might be because the increase in yield was of higher magnitude than the corresponding increase in consumptive use of water, which eventually resulted in considerable increase in water-use efficiency due to fertility levels.

The consumptive use and rate of moisture use also increased with different fertility levels, perhaps due to improved vegetative growth and extensive root system, which enabled the plants to utilize more moisture from soil layers. Singh *et al.* (1985) reported similar findings. Phosphorus and sulphur fertilization to crops induced deeper moisture extraction (Table 3). This might be attributed to increased root activity and proliferation of root system, due to translocation of more photosynthates to the roots, thereby resulting in greater extraction of moisture from the deeper layers (30-60 and 60-90 cm) of soil. However, under no-fertilization treatment the root growth was not much extensive and hence moisture extraction was confined to the upper soil layer (0-30 cm) only.

Economics

Pigeonpea + greengram intercropping system fetched higher net return as well as benefit : cost (B:C) ratio than sole pigeonpea on pooled mean basis (Table 3). This might be due to marginal difference in pigeonpea yield and additional yield of greengram, which resulted in higher net return in pigeonpea + greengram cropping system than in sole pigeonpea. Kantwa *et al.* (2005) reported similar results.

Moisture-conservation practices brought about considerable variation in net return and B:C ratio (Table 3). Maximum net return was recorded with soil mulch + FYM @ 5 tonnes/ha. This might be due to significantly higher pigeonpea-equivalent yield (Table 3) under this treatment and relatively low cost of inputs. The minimum net return and B:C ratio were recorded with soil mulch and soil mulch + FYM @ 5 tonnes/ha + kaolin 6 per cent spray respectively, perhaps due to relatively less addition to yield while the cost of input increased substantially due to application of kaolin.

The maximum net return and B:C ratio were observed with application of 40 kg P_2O_5 + 25 kg S/ha + PSB, followed by 40 kg P_2O_5 + 25 kg S/ha (Table 3). This could be attributed to significantly higher yield with 40 kg P_2O_5 + 25 kg S/ha + PSB over the control and lower cost of treatment.

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