Doubling the farm income through the promoting of pigeonpea based intercropping system: A review

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ABSTRACT
In order to ensure self-sufficiency, the current pulses requirement in the country is estimated at 22.5 MT. Keeping in view the trends in population growth rate and that several other options besides pulses are now available for meeting protein requirements of the people due to change in food habits of masses, the pulse requirement in the country is projected at 32 MT by the year 2030 and 39 million tonnes by the year 2050. This necessitates an annual growth rate of 2.2% requiring a phenomenal shift in research, technology generation, its dissemination, and commercialization along with capacity building in frontier areas of research. In every five year interval productivity will have to be enhanced by an average of about 80 kg/ha over the previous one to achieve a final productivity rate of 950 kg/ha by the end of 2025 and 1335 kg/ha by the end of 2050. The above-stated projections have been made assuming that practically it will be feasible to increase about 4 million ha additional area under pulses. The current per capita availability is estimated at 41.6 g/capita/day which was quite low (31.8 g) in 2000. Cultivation of pulses on poor soils under rainfed conditions with minimum inputs and care subject these crops to severe yield losses not only due to edaphic, abiotic and socio-economic factors but also due to confounding effects of various biotic stresses. High influence of environmental factors and their interactions with genotype are the major production constraint in pulses which lead to a limited gain in terms of productivity in most of the pulses. Therefore, for increasing of production of pulses, intercropping systems found to more beneficial in comparison to sole cropping systems in respect to profitability and soil fertility.

Key words: Crop equivalent yield, Intercropping, LER, Pigeonpea, Profitability, Soil health.

In the present scenario of degradation of natural resources i.e. soil, water and climate, the values of growing the pulses is more significance. Because of its imperative, grain-legumes are given a preference in the cropping systems of both irrigated and dryland areas (Kaur et al., 2015). Pulses are rich sources of protein especially for vegetarian. The most important feature of pulses is biological nitrogen fixation (BNF), which acts as mini-nitrogen factory in intensive cropping system and retain the productivity and sustainability. Pulses, in symbiosis with certain types of bacteria e.g. Rhizobium and Bradyrhizobium, are able to convert the atmospheric N into nitrogen compounds that can be used easily by growing the plants, consequently improving the soil health (Nulik et al., 2013). Additionally, phosphorous freeing properties, pulses helps in improving organic matter and microbial biomass and their activity (e.g. bacteria, fungi) in the soil. At the same period, rotations including legumes crop allow to continue the future production on same plot, pulses in intercropping systems not only allow a higher underground utilization efficiency due to their root structures but can reduce the pesticide utilization and deep rooting pulses like pigeonpea can supply the groundwater to intercropped the companion species. Finally, it is important to note that pulses are highly versatile and can be used in to minimize the weed problems under different agricultural production systems like intercropping, ley-farming and as cover crops (Hauggaard et al., 2008). Pulses can help mitigate the climate change due to reducing the dependency on synthetic or chemical fertilizers. The manufacture of these chemical fertilizers is energy intensive and emits greenhouse gases into atmosphere, thus their overuse is harmful to environment.

Pigeonpea (Cajanus cajan L.) is an important pulse crop, ranked 2nd important grain-legume of India after chickpea and cultivated an area of ~3.88 mha with a total production of ~3.17 mt and productivity of ~817 kg/ha (Anonymous, 2013). It is being rich in protein (22-23%) and having good source of nutrition to pre-dominantly vegetarian population in our country. Pigeonpea is the suitable for intercropping with different crops like cotton,
sorghum, pearl millet, mung bean, urd bean, maize, soybean and groundnut for increasing the system productivity and improving the soil health. Being excellent cover crops, it also plays a greater role in control of soil erosion through protecting it from direct rains (Mula and Saxena, 2010). The initial slow growth rate and deep root system of pigeonpea offers a good scope for intercropping with fast growing early maturing and shallow rooted crops (Nandhini et al., 2015). Pigeonpea has more advantages, when it is grown as intercropped. When it is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and having low harvest index (Willey et al., 1979); therefore it must be grown as intercrop, which helps in efficient utilization of available resources for enhancing productivity and profitability of the millions of farming community. Therefore, keeping the importance of intercropping system with pigeonpea this review has been prepared.

Effect of intercropping system on growth characters: The growth of pigeonpea during its initial stages is slow and accompanying intercrops enjoy unrestricted growth and almost no competition from pigeonpea during the first 3-4 months. By the time, intercrop is ready for harvest in October or November; pigeonpea crop gets well established with roots penetrating deep down in to the soils. This habit provides full opportunity for pigeonpea crop to grow during the next four to five months making more comprehensive use of land than by any alternative cropping system under the rainfed ecosystem. The crop growth rate of pigeonpea was much low at initial stages and increased with the age of the crop, reaching maximum (15-20 g/m²/day) at pod filling stage and declined in late pod filling stage (Pandey, 1980). Behara et al. (1996) revealed that compatibility of different intercrops with pigeonpea and found that the number of branches of pigeonpea was not markedly influenced by incorporating intercrops; however, plant height was markedly affected. Shivran and Ahlawat (2000), while working at IARI, New Delhi reported that plant height, branches and LAI in sole pigeonpea and pigeonpea intercropped with black gram did not differ significantly. Singh and Pal (2003) observed that plant height, dry matter production and leaf area index of pigeonpea were recorded higher in 1:1 row ratio than 2:2 row ratio of pigeonpea + maize intercropping system. Chaudhary and Thakur (2005) reported that the significantly maximum plant height and number of branches of pigeonpea were recorded, when grown as sole crop compared to intercropping with maize. While working on pigeonpea, Kumawat et al. (2012) reported that higher dry matter, CEC of roots and root N content were recorded in sole pigeonpea (60 cm) followed by normal planting (60×20 cm) + blackgram (1 row) and lowest in paired planting (80×40 cm and 20 cm) + blackgram (2 row). Kumawat et al. (2013a) while working at Varanasi reported intercropping systems paired planting of pigeonpea [40/80 cm×20 cm + blackgram 2 rows] gave taller plants and higher branches followed by normal planting and lowest in sole planting of pigeonpea. Nagar et al. (2015) reported that among the different intercropping system, pigeonpea + blackgram intercropping system recorded the maximum number of branches (16.31) and dry matter (97.53 g/plant) as compared to pigeonpea + greengram intercropping system. Srichandan et al. (2015) observed that taller plant height of pigeon pea, horizontal spread at 90 DAS and dry matter was in intercropped with groundnut, as compared to other intercropping systems. Pal et al. (2016), while working on pigeonpea found that among the intercropping systems pigeonpea + urd bean system shows superiority in growth characters compared to pigeonpea + sorghum.

Effect of intercropping system on yield attributes and yields: Ram et al. (2000) conducted an experiment at PDCSR, Meerut reported that pigeonpea gave 18.7 q/ha grain yield, whereas, pigeonpea + blackgram gave 18.8 q/ha grain yield of pigeonpea and 2.6 q/ha grain yield of blackgram. Verma (2001) working at Kaushambi reported intercropping of pigeonpea with urd bean gave highest pigeonpea grain yield (2122 kg/ha) compared to soybean (1998 kg/ha) and groundnut (2082 kg/ha). In an experiment conducted at Hisar, it was reported that pigeonpea (75 cm) + greengram (1:2) ratio gave the highest total yield (2352 kg/ha) over other different cropping systems (Kumar et al., 2003). Singh and Pal (2003) found that number of pods, pod length, weight, number of grains, 1000-grains weight grain and stalk yield were recorded in 1:1 pigeonpea + maize intercropping over 2:2 pigeonpea intercropping. Tomar et al. (2004) observed that sole cropping of pigeonpea gave significantly higher grain yield than the other both cropping systems (pigeonpea + mung bean and pigeonpea + cowpea), however, intercropping systems gave higher PEYs over sole pigeonpea. Chaudhary and Thakur (2005) reported from Bihar, seed yield of pigeonpea was higher in sole stand which was significantly superior to all other systems except pigeonpea + blackgram. The highest values of yield attributes of pigeonpea viz. pods, grains and 1000-grain weight were recorded under sole stand and the lowest when intercropped with maize and sesame owing to their canopy effect. Prakash et al. (2005) from Uttarakhand reported that higher mean seed yield : stalk ratio of pigeonpea in sole crop (60 cm) was 0.51, while under sole crop with paired rows (30/90 cm), it was 0.48 while in intercropping system, ratio varied from 0.53-0.58. Among paired planting intercropping, combinations of paired planting of pigeonpea + 1 row of groundnut proved superior thereby giving significantly higher pigeonpea yield (3.1 t/ha) compared to pigeonpea paired rows (30/90 cm) + 2 rows of groundnut (2.59 t/ha). Sharma et al. (2010) results revels that among the intercropping systems, pigeonpea+greengram recorded significantly higher values of yield attributes such as pods/
plant and seeds/pod of pigeonpea than pigeonpea + pearl millet intercropping system. Sharma et al. (2012) carried out an field experiment on pigeonpea based intercropping systems at Gulbarga, Dharwad and results revealed that pigeonpea + greengram intercropping recorded significantly higher pods/plant, seeds/pod and seed yield (14.43 q/ha) over pigeonpea + pearl millet intercropping system. While working on pigeonpea Kumawat et al. (2013b) recorded that maximum no. pods/plant, 1000-seed weight and seed yield of both crops (pigeonpea and blackgram) were recorded in sole planting followed by in normal planting. Nagar et al. (2015) conducted a field experiment at Akola and observed that maximum number of pods/plant (106.7), test weight (8.49 g), grain weight/plant (33.88 g) and HI (26.1%) were recorded in pigeonpea + blackgram system followed by pigeonpea + greengram system. While taller plants, seed yield, straw yield and biological yield (1601, 5146, 6710 kg/ha, respectively) were recorded under sole pigeonpea. Srichandan et al. (2015) found that maximum seed yield of pigeonpea was recorded in pigeon pea + rice intercropping system than rest of cropping systems. From Varanasi (UP), Pal et al. (2016) reported that highest yield attribute viz., number of pods, pod weight, weight of grains, test weight and yields as like grain yield and stalk yield of pigeonpea were recorded in pigeonpea + urdbean and lowest in pigeonpea + sorghum system.

**Effect of intercropping system on crop equivalent yield (CEY):** Crop equivalent yield is an important index in assessing performance of different crops under a given circumstance. Based on the price structure, economic yield of component crops is converted into base crop yield i.e. PEY. From Ambikapur (M.P.), Dubey et al. (1991) indicated that PEYs was increased by 33 per cent when pigeonpea was intercropped with soybean or blackgram in 1:1 row proportion over sole pigeonpea. Ahmed (1991) results revealed that maximum PEY was recorded from intercropping of pigeonpea and groundnut in various row proportions compared to sole pigeonpea. Prasad and Srivastava (1991) reported that there was an increase of 50% PEY by planting of one row of soybean in between two rows of pigeonpea spaced at 60 cm apart. Singh and Singh (1994) reported that intercropping of pigeonpea + sesame and pigeonpea + groundnut gave higher pigeonpea equivalent yield compared to the sole pigeonpea. While working on pigeonpea Dwivedi and Bajpai (1997) reported that pigeonpea + groundnut intercropping (1:1 row ratio) gave maximum pigeonpea equivalent ratio (2,070 kg/ha), over other cropping systems. Rana and Pal (1997) on pigeonpea based intercropping systems concluded that pigeonpea (50 cm) + 1 row of cowpea gave higher seed yield and PEYs over the other intercropping system. Sharma et al. (1998) recorded significantly higher PEY (2925 kg/ha) was recorded with pigeonpea + sesame in 2:2 row proportion over 2:4 row proportion (2599 kg/ha) and sole crop of pigeonpea (2425 kg/ha). Mishra and Ali (1998) reported higher pigeonpea equivalent yield from the 2:2 row ratios pigeonpea-sorghum intercropping system as compared to 2:4 row ratio. Singh and Rahman (1999) indicated that highest PEY (2340 kg/ha) was found in pigeonpea + groundnut system in 1:2 row proportion. Prasad and Yadav (2001) reported that highest PEYs (2061 kg/ha) was recorded in pigeonpea + soybean system (2:2 row ratio), which proved significantly superiority over sole pigeonpea. Bhagat (2002) conducted an experiment to assess the feasibility of intercropping of maize under rainfed condition and result revealed that highest PEY of 11.21 q/ha (6.72 q/ha from pigeonpea and 13.27 q/ha from maize) was obtained in paired row of pigeonpea and maize at 60 x 30 cm being on par with maize and pigeonpea in alternate rows at 60 x 30 cm. Among cropping systems, intercropping of pigeonpea + frenchbean (2932 kg/ha) and groundnut (2406 kg/ha) gave significantly higher PEYs over sole pigeonpea and rest of intercropping systems. Kumar et al. (2005) working on pigeonpea at Kanpur reported higher PEYs (1993.60 kg/ha) with pigeonpea + groundnut compared to sole pigeonpea. Verma et al. (2005) working on pigeonpea reported higher PEY from all intercropping systems over sole crop of pigeonpea and fodder sorghum. However, they observed significantly higher PEY (34.4 q/ha) from narrow spaced pigeonpea (75 cm) intercropped with fodder sorghum in a row ratio of 1:2 over other intercropping systems. Mall Reddy et al. (2007) reported significantly higher PEY (2232 kg/ha) from pigeonpea + groundnut cropping system than that of pigeonpea + sorghum cropping system (1313 kg/ha) at similar level of pest and nutrient management practices. Kumar and Rana (2007) at New Delhi, reported that PEY and economics with treatment planting of one row of greengram between paired rows (30/70 cm) of pigeonpea proved superior over sole pigeonpea. Rekha and Dhurua (2009) at ARS, ANGRAU, Adilabad during kharif and found that highest PEYs was recorded under planting of pigeonpea variety MRG-66 (150 cm) + 5 rows of soybean as intercrop followed by pigeonpea variety MRG-66 (150 cm) + 3 rows of soybean. Sharma et al. (2010) working on pigeonpea found that highest PEY was recorded in pigeonpea + greengram system (14.15 q/ha), and lowest in pigeonpea + pearl millet intercropping system (12.75 q/ha). Singh et al. (2012) found that pigeonpea + blackgram system gave the PEY significantly over sole pigeonpea and pigeon pea + maize. Sharma et al. (2012) working on pigeonpea found that pigeonpea + greengram intercropping systems recorded significantly higher PEYs (17.13 q/ha) over pigeonpea + pearl millet system. Kathmale et al. (2014) reported that among pigeonpea based intercropping systems, pigeonpea + groundnut (1:3) recorded maximum PEY (1425 kg/ha) followed by pigeonpea + soybean (1:3), whereas, maximum
LER was in pigeonpea + soybean (1:3) intercropping system. Kumawat et al. (2015) among intercropping system maximum LER was recorded with normal intercropping system (60 × 20 cm + blackgram 1 row), which was statistically similar to paired planting of pigeonpea [40/80 cm × 20 cm + blackgram 2 rows].

**Effect of intercropping system on land equivalent ratio (LER):** Land equivalent ratio reflects the advantage of intercropping over sole cropping system. The obvious reason for large yield advantage in intercropping system is that component crops differed in their use of natural resources and utilized them more efficiently resulting in higher yields per unit area than that produced by their sole crops. Dwivedi and Bajpai (1997) reported that pigeonpea + groundnut intercropping (1:1 row ratio) gave maximum LER (1.47) over rest of systems. Omprakash and Bhushan (2000) found that pigeonpea/castor + greengram intercropping showed highest LER (1.62 and 1.61) and pigeonpea/castor + pearl millet lowest LER (1.16). Pigeonpea and castor based intercropping systems recorded 16-61 and 16-62% higher LER values, respectively than sole cropping. Chaudhary and Thakur (2005) found that among the intercropping the highest LER of 1.55 was recorded under pigeonpea + maize followed by pigeonpea + blackgram (1.52). Rekha and Dhuru (2009) reported that planting of pigeonpea variety MRG-66 at 180 cm + 6 rows of soybean gave maximum (1.39) LER over rest of the intercropping systems. Rao et al. (2009) conducted an experiment during 2005–07 to study the effects of intercrop row ratio and nitrogen on sorghum + greengram which resulted in highest LER (1.32) and price equivalent ratio (1.23). Kumawat et al. (2015) reported that maximum pigeonpea equivalent yield and production efficiency was recorded in normal intercropping system (60 × 20 cm + blackgram 1 row) which was statistically similar to paired planting of pigeonpea [40/80 cm × 20 cm + blackgram 2 rows].

**Effect of intercropping system on quality, nutrient content and their uptake:** Dayal et al. (1987) reported that nutrient uptake by pigeonpea in mixed stand was significantly reduced compared to pigeonpea in pure stand, but total nutrient uptake by maize and pigeonpea intercropping system was higher when grown in mixed stand. The nutrient uptake by pigeonpea was reduced, when sown in paired rows, however, uptake by intercrops grown between paired rows of pigeonpea was significantly higher than, uptake by intercrops grown between uniform rows of pigeonpea (Reddy and Havanagi, 1991). The concentration of N and P was increased, whereas concentration of K was decreased in pigeonpea seeds by intercropping with soybean (Kulhare and Tiwari, 1989). Morris and Garrity (1993) found that total uptake of P and potassium was increased in intercropping systems. On an average, intercropping increased the P and K uptake by 43 and 35%, respectively, over sole. Rana et al. (1999) reported significant reduction in N, P and K uptake by pigeonpea, when intercropped with greengram. Ram et al. (2000) reported pigeonpea + blackgram-wheat system removed higher P (60 kg/ha) compared to pigeonpea—wheat system (46 kg/ha). Prakash et al. (2005) from Uttarakhand reported that paired planting of pigeonpea (30/90 cm) have been reported the highest N and P uptake under pigeonpea + groundnut (2:1), whereas K uptake was higher in sole pigeonpea. Kumar and Rana (2007) reported that significantly increased total uptake of P and S with sole pigeonpea over pigeonpea + greengram intercropping, however cropping systems had no marked influence on P and S uptake by grain and stover of pigeonpea. Kumar et al. (2013a) reported that significantly improved total uptake of NPKS and Zn by pigeonpea with sole pigeonpea followed by normal intercropping and lowest was in paired intercropping. Tuti et al. (2013) reported that highest NPK uptake by crop was recorded in pigeonpea-lentil system compared to rest of cropping systems. From Akola Nagar et al. (2015) reported that highest N, P and K uptake (92.5, 9.6, 58.4 kg/ha respectively) were recorded in sole pigeonpea. Whereas, in case of total nutrient uptake highest N and P uptake (105.8 and 19.3 kg/ha), respectively was recorded with pigeonpea + blackgram system over remaining intercropping system, but total uptake of K (58.4 kg/ha) was in sole pigeonpea. Rai et al. (2015) at Rewa (MP) found pigeonpea + greengram system produced higher LER and CEY followed by pigeonpea + blackgram and lowest was in sole pigeonpea.

**Effect of intercropping system on profitability:** Growing of greengram, blackgram or soybean an in intercrop in pigeonpea was more remunerative than practice of growing pigeonpea alone. Nimje (1995) reported that maximum benefit: cost ratio (2.80) were recorded with the 1:3 row ratio (pigeonpea: soybean) followed by 1:2 row ratio. While working on pigeonpea, Dwivedi and Bajpai (1997) found that maximum net income (Rs 13,688) and benefit: cost ratio (2.80) were recorded with the 1:3 row ratio compared to other cropping systems. Shivran and Aulawat (2000) working at IARI, New Delhi reported that pigeonpea/blackgram intercropping fetched highest net returns (Rs 23,867/ha) compared to sole pigeonpea (20,621/ha). Kumar et al. (2003) reported pigeonpea (75 cm) + greengram (1:2) ratio gave maximum net returns and benefit: cost ratio (2.09) over other intercropping systems. Higher benefit: cost ratio was observed under pigeonpea + groundnut systems by Jat and Aulawat (2004). Yadav et al. (2005) reported that intercropping of pigeonpea with urdbean in 2:1 ratio recorded the maximum gross return (Rs. 37333/ha) and net returns (Rs. 27326/ha) and net return per rupee investment (Rs. 2.73). Similarly, Kumar et al. (2005) from Kanpur reported that pigeonpea + urdbean gave the highest net return of Rs. 14005/ha and was closely followed by
pigeonpea + groundnut with Rs. 13277/ha. However, sustainable yield index (0.72) was highest in pigeonpea + groundnut and sustainable value index was highest (0.76) in pigeonpea + urdbean. The highest net return on per rupee investment was obtained with pigeonpea + urdbean (1.37). Kumar and Rana (2007) reported that pigeonpea + greengram system fetched higher net returns and B:C ratio over sole pigeonpea. Sharma et al. (2010) reported that pigeonpea + greengram system gave significantly higher gross returns (Rs. 34265/ha), net returns (Rs.26154/ha) and B:C ratio (3.21) as compared to pigeonpea + pearl millet intercropping system. Sharma et al. (2012) reported maximum gross returns (Rs. 40983/ha), net returns (Rs. 32499/ha) and B: C ratio (3.81) was recorded in pigeonpea + greengram intercropping systems as compared to pigeonpea + pearl millet intercropping system. Kumawat et al. (2013b) working on pigeonpea and reported maximum gross returns, net returns, B:C ratio, economics efficiency and monitoring advantage index (MAI) were fetched with normal planting of pigeonpea (60 × 20 cm + blackgram 1 row) followed by paired planting of pigeonpea [40/80 cm × 20 cm + blackgram 2 rows]. Tuti et al. (2013) showed pigeonpea-lentil system proved superiority in terms of system net returns (Rs. 63616/ha), B: C ratio (1.64) and energy ratio (1.94) as compared to pigeonpea-wheat, pigeonpea-barley, pigeonpea-fieldpea and pigeonpea-toria cropping systems. Kathmale et al. (2014) reported among pigeonpea based intercropping systems, pigeonpea + groundnut (1.3) fetched maximum gross returns and net returns whereas, B: C ratio was in pigeonpea + soybean (1.3) system. Rai et al. (2015) at Rewa (MP) and found that pigeonpea + greengram system fetched maximum gross returns, net returns and B: C ratio followed by pigeonpea + blackgram and lowest was in sole pigeonpea. Srichandan et al. (2015) observed that pigeonpea + rice gave the maximum net return and benefit: cost ratio over the rest of intercropping systems.

Effect of intercropping system on soil health: Legumes are known for their unique to enrich the soil through fixation of free nitrogen form atmosphere. Secretion of nitrogen from root of legumes stimulates the growth of associated non-legumes (Guljaev and Rousel, 1963). Yadav (1981) stated that increase in the soil nitrogen content after pigeonpea was due to substantial nodulation. Inclusion of pigeonpea as intercrop in sorghum (1:1 rows) reduced the fertilizer nitrogen need of sorghum (Naraian et al., 1980). The available phosphorus and potassium content of the soil did not show appreciable variation (Muthuvel et al., 1984). Singh and Faroda (1986), while working on pigeonpea during kharif season at Hisar (Haryana) found that when pigeonpea + mungbean intercropping significantly enhanced total soil N and P after harvest of crop over sole pigeonpea during the both the years. From Varanasi Kumawat et al. (2012) reported that among the intercropping system, higher available N, P and K in soil were recorded in sole planting followed by in normal planting and lowest in paired planting of pigeonpea. Singh et al. (2012) field experiment was conducted during kharif seasons of 2007 and 2008 at Pantnagar reported that blackgram intercropped with pigeonpea recorded higher values of organic carbon (OC), available N, P, K contents, microbial population and dehydrogenase activity in soil compared to sole pigeonpea and pigeonpea + maize intercropping system. Tuti et al. (2013) results showed that available nutrient status (organic carbon, N, P and K) in soil improved significantly due to pigeonpea-lentil system. From Akola Nagar et al. (2016) reported significantly highest soil microbial biomass carbon (SMBC) and microbial population (fungal, bacterial and actinomycetes); and lower bulk density, pH and EC, higher OC and available N, P, K and were noted under pigeonpea + blackgram and pigeonpea + greengram intercropping over sole pigeonpea.

CONCLUSION

Intercropping offers farmers opportunity to engage nature’s principle of diversity on their farms. Intercrops can be more productive than the growing of sole cropping. Also insect-pest and diseases management benefits can be realized from intercropping due to increased diversity. Biological efficiency is likely to improve when legumes are included in the cropping system as intercropping because they explore the same soil mass more thoroughly, compared to sole cropping and may be able to take up the nutrients from a place and a form which are inaccessible So that overall productivity of intercropping with legume and cereals relies on main crop as well as compatibility with other crops.

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