Pearl millet \([\text{Pennisetum glaucum L.}]\) intercropping with pulses step towards increasing farmer’s income under rainfed farming: A review

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Abstract
Pearl millet occupies the prime position in the rainfed farming in arid and semi-arid regions of India. Its adaptation to higher temperature, scanty rainfall, poor fertile soils etc leads its more importance in climate change scenario. Its sole cultivation is often risky and to avoid risks in rainfed areas, generally farmers grow green gram, cowpea, moth bean, black gram and cluster bean in mixed stand as well as in intercropping. Additionally limiting land resources equipped with poor soil fertility status leads to finding way for efficient resource utilization with enhancing productivity per unit area and time, which can be obtained by intercropping and legume based intercropping witnessed higher production with additional benefits which make this more suitable intercropping choice. This review supporting the production scenario of pulses intercropped with pearl millet is presenting in paper to help farmer in making decisions regarding crop selection.

Keywords: Intercropping, yield attributes and yield, pearl millet and legumes

1. Introduction
Pearl millet \([\text{Pennisetum glaucum L.}]\) occupies third position in food grain crop after wheat and barley in India. It is commonly known as Bajra, Indian millet, Bulrush millet, Cattail millet and Pencillaria. It possesses drought-escaping mechanism besides having inherent adaptation to drier and low fertile soils which leads to its prime position in dryland agriculture. Additionally, it is a rich source of minerals, vitamins, fibres etc. and thus contributes to securities of food, nutrition, fodder, fibre, health, livelihood and ecology (Changmei and Dorothy, 2014) \(^1\).

Today, it is getting more attention due to increasing evidence of low and erratic precipitation, terminal heat, frequent occurrence of extreme weather events coupled with scanty water resources. It occupies a distinct position in agricultural economy of the country (Ansari et al., 2012) \(^2\). India is the largest producer of pearl millet in the world with 7.1 million hectare area and 9.1 million tonne per year grain production with average productivity of 12.72 q/ha during 2015-16 (Anonymous, 2016) \(^3\). In India, pearl millet, which accounts for more than 90% of the total area under it, is mostly cultivated in the state of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana.

Limited availability of land resources and declining soil fertility both globally and as well locally, heightened the concerns regarding agriculture’s ability to sustain the demands of ever increasing population. To increase and sustain agriculture productivity we have to look for the ways of using available land and resources more effectively than in the past. This objective can be achieved by intercropping, which is an effective practice to augment the total productivity per unit area of the land per unit time by growing more than one crop in the same field, with the prime objective of better utilization of available environmental resources. Earlier, the concept of mixed and intercropping was for subsistence farming, but now a days, this concept has been changed into maximization per unit area and time.

The basic concept of intercropping system involves growing together two or more crops with the assumption that two crops can exploit the environment better than one and ultimately produce higher yield since the component crops differ in resources use and when grown together, they complement each other and make overall better use of resources (Yadav et al., 2015) \(^4\). Intercropping is growing two or more crops simultaneously on same piece of land in distinct row arrangement with the objectives to optimize the use of natural resources, to stabilize the yield of crops and to obtain higher economic returns (Willey, 1979; Thakur et al.,...)
Intercropping with specific planting geometry and selection of compatible crops is a profitable practice to make use of available light, soil moisture and nutrients more efficiently thus, improving productivity of dryland crops (Kaushik and Gautam, 1987) [8]. The biggest complementary effect and yield advantages occur when the component crops have different growing periods to make their major demand of resources at different time. Therefore, the crops, which mature at different time thus separating their periods of maximum demand for nutrients, moisture, space and light, could be suitably intercropped (Enyi, 1977) [9].

Research work in rainfed areas has shown that intercropping with better selection of compatible crops and proper nutrient management is a profitable practice to make use of available soil moisture and nutrients more efficiently and per se, improving productivity of dryland crops (Goswami et al., 2002) [10]. Most suited intercrops with pearl millet are green gram, black gram, pigeon pea, cowpea and cluster bean. Intercropping of either of these legumes increased the land equivalent ratio and monetary returns considerably (Bhatnagar et al., 1998) [11]. This review is for providing essential knowledge to farmers and research scientists regarding the benefits of pulse based intercropping in pearl millet in terms of equivalent yield, land and resources utilization, yield attributes and yield in pulses intercropped with pearl millet.

2. Benefits of legume based intercropping
Pulse based intercropping in cereals have many advantages as both differ in their growth behavior and input requirements which leads to efficient utilization of resources and increasing productivity with enhancement in soil health by taking advantage of biological nitrogen fixation by pulses. Intercropping may also increase the production per unit time without affecting the production of main crop to a great extent when leguminous crops are used as intercrop, improve soil fertility by fixing atmospheric nitrogen (Donald, 1963; Aiyer, 1967; Francis and Heicnel, 1973) [12-14]. Presence of leguminous crops in the mixture benefits the associated non-leguminous crops, as they provide a portion of biologically fixed nitrogen to non-leguminous components (Kurdali et al., 2003) [15]. Further, the leguminous crops increase content of nitrogen in soil and help in maintaining soil fertility (Gregorich et al., 2001; Gathumbi et al., 2003) [16, 17]. Intercropping also helps in improving the efficiencies of nutrients, moisture, light and better management of pest control, which ultimately leads to higher productivity (Baldev et al., 2005) [18].

Yield improvement by intercropping is attributed mainly to the complementary effects (Jensen, 1996) [19], better resource use efficiency of the intercrops and buffering effects of the intercrops against weeds and diseases (Willey, 1979; Anil et al., 1998; Siner et al., 2000; Deksen et al., 2002) [20, 23]. Intercropping positively helps in the soil conservation by improving soil fertility (Jarenyma et al., 2000) [24].

3. Effect of intercropping on growth parameters
Intercropped plants may decrease, increase, or maintain their normal height depending on the nature of interference of the component crops. Misra (1996) [25] recorded more plant height of both cluster bean (base crop) and pearl millet (intercrop) under triple rows of cluster bean at 30.90 cm + 3 rows pearl millet planting system. He further reported lower dry matter per plant in cluster bean under intercropping system with minimum dry matter under triple row system, whereas, dry matter of intercrop (pearl millet) did not vary under different intercropping systems. Singh and Khan (2003) [26] observed that intercropping did not affect the crop growth negatively. Yadav et al. (2015) [27] observed that the main crops (moth bean and cluster bean) and the intercrop (pearl millet) recorded the maximum plant height under 5:1 planting system.

The sole pearl millet recorded significantly more number of tillers per plant than the intercropping systems of pearl millet + green gram, pearl millet + cluster bean and pearl millet + cowpea (Baldev et al., 2003) [28]. Baldev et al. (2005) [29] observed maximum plant height of sole pearl millet, however, being at par with the height under pearl millet + cluster bean intercropping system. Ansari et al. (2012) [30] reported an average increase of 9.62 cm in plant height and 1.9 in number of tillers per metre row length in sole stand of pearl millet than intercropping system at maturity stage. Intercropping system decreased the leaf area index by 6.5 and 11.1 per cent over sole cropping of pearl millet at 60 DAS and maturity stage, respectively. The crop growth rate of sole stand increased 12.2 per cent during 30-60 DAS over intercropping system.

4. Yield attributes and yield
Yield of a crop is the function of interaction between genetic potential of the crop cultivar and the environment. When two or more crops are grown in association, the genetic potential being constant, environment component is modified, per se affecting the different components of yield. Singh et al. (1981) [31] found that intercropping of green gram and cluster bean in between the rows of pearl millet had no adverse effect on its grain yield and gave additional grain yield of 100-163 and 564-895 kg/ha, respectively. Anjeneyula et al. (1982) [32] reported that intercropping of pearl millet triple rows 30 cm apart in an interspace of 90 cm between 2 rows of Vigna radiata increased the Vigna radiata yield by 13-16 per cent as compared with intercropping in paired rows 30 cm apart in interspaces of 70 cm and the total yield of all the intercropping systems was higher than the yield of pearl millet in pure stand.

The paired rows of pearl millet and 100 cm uniform row spacing with two rows of cluster bean gave additional yield of 4.7-6.2 q/ha under rainfed conditions and no adverse effect was observed on grain yield, stover yield and 1000 grain weight of pearl millet crop (Singh, 1985) [33]. Rana et al. (1986) [34] tried pearl millet in rows 45 cm apart or paired rows 30 and 60 cm apart alone or intercropped with mung bean or cluster bean and found that pearl millet grain yield was not affected by intercropping except when grown in rows 45 cm apart or intercropped with mung bean. Pearl millet in paired rows with cluster bean intercropped between wider row spacing gave the highest grain equivalent yield of pearl millet. Kaushik and Gautam (1987) [35] showed that productivity per unit area increased considerably when pearl millet was intercropped with one row of cowpea or green gram in paired rows.

The paired rows of pearl millet intercropped with 1 or 2 rows of cluster bean produced grain yield of 8.4 and 8.6 q/ha as compared to 7.5 and 8.8 q/ha of pearl millet in paired rows and uniform rows in pure stand whereas, cluster bean gave the additional seed yield of 2.4 and 3.2 q/ha, respectively (Sharma et al., 1988) [36]. Out of three leguminous crops as intercrop,
the cluster bean crop proved superiority over cowpea and green gram at Jobner, Rajasthan and gave 2.95 q/ha additional seed yield when two rows of cluster bean were sown in between paired rows of pearl millet (30:60 cm) with application of nitrogen at 30 kg/ha (Bhati and Manohar, 1989) [37].

Pearl millet and cluster bean grown in alternate rows (1:1) gave mean combined dry matter yield at par with sole cropping of pearl millet but significantly higher in the range of 42-194 per cent than mixed, intercropping and strip cropping. The 1:1 system also produced maximum grain yield among different intercropping systems (Singh and Joshi, 1994) [38]. Similarly, Singh et al. (2005) [39] observed that intercropping of one row of green gram and pearl millet in 30:70 cm paired row planting of cluster bean decreased the cluster bean yield by 24.7 and 24.1 per cent as compared to sole crop in paired row but produced additional yield of 2.22 and 8.35 q/ha of green gram and pearl millet, respectively. The yield of sole pearl millet (1525 kg/ha) and from the crop intercropped with leguminous crops (1528, 1498, or 1540 kg/ha) were statistically the same and the yield from intercrop legumes was obtained as a bonus (Sharma and Gupta, 2001) [40]. Prasad and Nanwal (2001) [41] recorded significantly higher pearl millet grain equivalent yield (15.3 per cent) in pearl millet intercropping with mung bean as compared to sole pearl millet. Hooda et al. (2004) [42] observed that the grain and stover yield of pearl millet were statistically at par in both pearl millet + green gram intercropping system and sole pearl millet. Inter or strip cropping of leguminous crops (green gram, cluster bean and cowpea) in 2:1 to 8:4 row ratio had no significant adverse effect on grain yield of pearl millet as compared to sole planting (Sharma and Singh, 2008) [43]. Ansari et al. (2011) [44] found that pearl millet + pigeon pea intercropping system recorded significantly higher pearl millet equivalent yield (4.31 and 4.82 q/ha, respectively) over the sole stand of component crops. Ansari et al. (2012) [45] also observed that pearl millet intercropped with pigeon pea recorded significantly higher pearl millet equivalent yield (PEY) as compared to either of sole cropping. The highest yield attributes viz., grain weight per earhead (14.25 g), test weight (8.56 g), earhead diameter (3.13 cm), earhead length (14.25 cm) and earhead weight (31.15 g) of pearl millet were recorded in pearl millet + mung bean cropping system with 2:2 row ratio followed by pearl millet + mung bean cropping system in 2:1 row ratio, whereas, the maximum grain (1568 kg/ha), straw (5192 kg/ha) and biological yield (6760 kg/ha) were recorded in pearl millet sole crop as compared to intercropping treatments.

5. Intercropping assessment

There are number of ways of ensuring that intercropping advantages are accurately assessed, and the most common is the calculation of land equivalent ratio i.e. LER (Willey, 1979) [46]. Mead and Willey (1980) [47] pointed out that the LER of 1.2 indicated a yield advantage of 20 per cent. Rao and Willey (1980) [48] suggested that differences in maturity periods of the component crops usually resulted in quite higher yield. Better results of land use (LER) have been observed in the intercropping system than the sole crops (Ennin et al., 2001; Adeniyan and Ayoola, 2006 and Muoneke et al., 2007) [49-51]. Singh and Joshi (1980) [52] observed 21 per cent advantage in LER with double row of cluster bean planted in inter-row spaces of paired pearl millet (30/70 cm). Patel et al. (1998) [53] found that based on net realization, benefit-cost ratio and LER, the pearl millet intercropped with cluster bean with a row ratio of 2:1 was superior among different intercropped treatments. Singh and Joshi (1994) [54] found that the pearl millet-green gram strip cropping (4:4) showed the highest land equivalent ratio of 1.26 indicating 26 per cent advantage over sole cropping. Sharma and Gupta (2001) [55] recorded the highest value of land equivalent ratio (1.21) for pearl millet + cluster bean cropping system, which gave significantly better results than the pearl millet + cowpea cropping system. Samba et al. (2007) [56] found that the pearl millet-cowpea intercropping system was more productive than their mono-crops as proved by the LER value of 1.2. Osman et al. (2011) [57] reported the LERs value larger than unity, indicating benefits of intercropping over sole cropping of millet.

Varia and Sadhu (2011) [58] observed the highest value of LER and relative crowding coefficient (RCC) for all the treatments of pearl millet intercropped with green gram than pearl millet sole and also observed that RCC was highest (3.47) in row ratio of 1:2 followed by RCC value of 2.04 under pearl millet + green gram in 1:1 ratio. Dwivedi et al. (2015) [59] observed that the pearl millet-cowpea intercropping was more productive than their mono-crops, which was proved through the LER value of 1.2. The land equivalent ratio, area-time equivalent ratio, aggressively, competition ratio, monetary advantage index and crowding coefficient of green gram and cowpea in 8:4 and 6:3 strip cropping systems with pearl millet showed their superiority over other inter or strip cropping systems (Sharma and Singh, 2008) [59]. Singh et al. (2005) [60] reported that intercropping of both pearl millet and green gram in cluster bean was compatible as witnessed by higher values of biological parameters like land equivalent ratio, area time equivalent ratio, income equivalent ratio, monetary advantage index and crowding coefficient than sole cluster bean planting.

Kuri et al. (2012) [61] observed that the intercropping of pearl millet with moth bean in 1:7 row ratio closely followed by 4:4, 2:6 and 3:5 row ratio produced maximum pearl millet equivalent yield, LER and net returns as compared to sole and other intercropping treatments. Aggressively values showed that intercropping of moth bean did not offer any competition to pearl millet in different row ratio, while RCC values indicated that there was a yield disadvantage in moth bean in all the intercropping systems except 1:7 row ratio.

6. Economic returns

Alternate rows of cluster bean and pearl millet in 1:1 ratio gave significantly higher monetary returns than other intercropping systems, sole crop treatments and conventional systems of broadcasting of crop-mixtures (Singh, 1977) [63]. Singh and Joshi (1994a) [64] found the highest gross (Rs.7512/ha) and net returns (Rs. 5844/ha) with alternate row intercropping system (1:1) of pearl millet and guar, followed by sole cropping of pearl millet. Similarly, at RRS Bawal (Haryana), two rows of cluster bean sown in interspaces of pearl millet gave higher gross returns as compared to sole crop of pearl millet and even proved better than sole crop of cluster bean (Singh, 1981) [65]. Intercropping of 1 or 2 rows of cluster bean earned higher net returns without causing yield reduction in the base crop of pearl millet at Jobner (Sharma et al., 1988) [66]. Among intercropping of pearl millet (Pennisetum glaucum) with green gram (Vigna radiata)/moth...
bean (Vigna aconitifolia) or cluster bean (Cyamopsis tetragonoloba) in 4:4, 4:3, 4:2, or 4:1 ratio. Singh (1994) [67] found the maximum net returns with moth bean in 4:1 ratio. Singh et al. (2003) [68] reported that intercropping of green gram with cluster bean paired row planting was more profitable than the other intercropping treatments in terms of cluster bean equivalent yield (17.7 q/ha), net return (Rs. 6846/ha) and income equivalent ratio (1.9).

Hooda and Khippal (2000) [69] recorded the highest gross as well net monetary returns of Rs. 19119 and 12270 per ha in pearl millet + green gram (30/60 cm) intercropping system. This system also recorded benefit-cost ratio of 2.75 which further witnessed the profitability of intercropping system. Hooda et al. (2004) [70] recorded higher gross (Rs. 24434/ha) as well as net monetary returns (Rs. 16043/ha) from the intercropping of pearl millet + green gram system which were higher by Rs. 3663 and 2923, respectively over sole pearl millet crop. Intercropping of pearl millet with green gram also recorded higher benefit-cost ratio of 1.90 which further witnessed the profitability of this system. Kumar et al. (2005) [71] also found that intercropping of guar in pearl millet gave more net returns (Rs. 6647) and benefit-cost ratio (1.98).

7. Conclusion

Based upon the literature cited above, it is concluded that the intercropping of pearl millet with pulses brought out earliness in phenological while the growth attributes (plant height, LAI, LAD, total tillers and dry matter accumulation per plant) and yield contributing traits (effective tillers per plant, earhead length, earhead girth and test weight) of pearl millet were decreased by the intercropping with different pulses. However, all the intercropping system in terms of pearl millet equivalent yield (PEY), the gross returns, net returns and benefit-cost ratio exhibited their superiority over their respective sole stands which in turns increasing farmer’s income as compared to sole stand and reduce the risk of main crop failures.

8. References

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