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Review Paper

Potential and Advantage of Pearl Millet- Legume Intercropping System: A Review

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ABSTRACT

In the present context of climate change and declining productivity of major crops, it is important to cultivate an environmentally friendly crop. Millets are ecologically sound and can be grown under diverse agroclimatic conditions. Millet-based cropping system is common in dryland and rainfed conditions. Pearl millet (*Pennisetum glaucum* L.) has a wider adaptability for different agroclimatic conditions and seasons, even it is suitable for intercropping system. In pearl millet-based intercropping system, crop choice, crop maturity, plant stand and planting geometry, and planting time are the key considerations which determine the success of the intercropping system. Earlier researches have documented the benefits of pearl millet-based intercropping system in terms of resource use efficiency and yield benefits. The present review article focuses on the key considerations while choosing pearl millet-based intercropping system and its holistic benefits on land resource use efficiency and enhanced productivity.

HIGHLIGHTS

- In the present consequences of climate change impacts on agriculture, ecologically hardy millets can be chosen.
- Pearl millets is an environmentally friendly crop that can be adopted under diverse cropping system.
- Pearl millet-based intercropping system has multifaceted benefits in terms of resource use and productivity enhancement.

Keywords: Agroclimatic conditions, intercropping system, Pearl millet, crop maturity, crop choice

The current agricultural system is facing tremendous problems, including dwindling natural resources and diversity, depletion of soil, water, and air quality, along with declining factor productivity and net revenue generation from agriculture (Shankar *et al*. 2020; Sagar *et al*. 2023; Sairam *et al*. 2023a). Food grain production in developing countries like India must keep up to fulfill the need of an ever-increasing population. Unless food grain output is boosted, there will be shortage of food in the future. Due to the limited supply of land resources and declining soil fertility both globally and locally, it will be a challenging task to meet the future demand of growing population (Maitra and Ray, 2019; Billah *et al*. 2021). The climate change and global warming and associated abiotic stresses further created uncertainty in agriculture (Pramanick *et al*. 2021; Sagar *et al*. 2022). Restoration of agricultural ecosystem variety and good management is one of the most important methods in sustainable agriculture.

In this regard, adoption of intercropping system can be considered which can ensure sustainable intensification crops with a greater ecosystem service. Intercropping is an effective approach that boosts

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total production per unit area (Gitari *et al*. 2020; Maitra *et al*. 2001a). Intercropping is the practice of cultivating two or more crops simultaneously on the same piece of land in different row proportion with an emphasis to maximize the use of available natural resources, stabilizing crop yields, and enhancing economic returns further resulting in agricultural sustainability (Maitra *et al*. 2019; Maitra *et al*. 2001b). Intercropping decreases the risk of crop failure because of serious disease infestation or insect pest attack as two crops are grown on the same crop field (Maitra 2020; Mir *et al*. 2022). Intercropping system enhances better use of the available land, light, soil moisture, and nutrients. The complementarity effect and productivity increases are highest when the component crops have diverse growing habitat to meet their significant resource demands at different times (Maitra *et al*. 2000; Maitra *et al*. 2021; Panda *et al*. 2022). More consistent yields, greater nutrient recycling, improved weed, pest, and disease management, and increased biodiversity are among advantages of intercropping systems. These advantages are mostly attributable to the complementary use of environmental resources by the component crops (Sarkar *et al*. 2000; Dwivedi *et al*. 2015; Sahoo *et al.* 2023). The combination of cereal and legumes in intercropping system is a wise approach for sustaining crop productivity.

During recent times, it has been observed that there is a stagnation of productivity of fine cereals, namely rice and wheat. On the other hand, the coarse cereals are food grains which are neglected; however, they have the potential to contribute in the food basket in future as they are ecologically sound in nature (Maitra *et al*. 2022). Pearl millet (*Pennisetum glaucum* L.) also known as *bajra*, is the sixth major grown crop next to wheat, rice, corn, barley and sorghum in the world. In tropical semi-arid regions of the world, pearl millet is a prominent cereal that is largely raised in Africa and Asia. The ability to withstand drought and extreme weather conditions under unproductive soils makes the crop more suitable for dryland farming. Pearl millet is also known for nutri-cereal for its nutritional value as it contains 13-14 per cent protein, 5-6 per cent fat, 74 per cent carbohydrate and 1-2 per cent minerals. It also contains higher amount of carotene, riboflavin (Vitamin B2) and niacin (Vitamin B4) (Singh *et al.* 2016). It is used as poultry feed and green fodder for cattle. Today it is gaining more attention due to its higher potential among all other millets. It has distinct role in nation's agricultural economy. In India pearl millet occupied an area of 7.57 million ha with an average production of 10.86 million tones and productivity of 1436 kg ha^{-1} during 2020-21 (GOI, 2021). More than 90% of the area under pearl millet cultivation in India is found in the states of Rajasthan, Uttar Pradesh, Gujarat, Maharashtra, and Haryana. Pearl millet is produced in arid and semi-arid regions with several limitations and it is better to adopt an intercropping system with pearl millet to harness more profitability and efficient use of resources. The article focuses the potential of pearl millet- legumes intercropping system based on the earlier research.

Consideration for intercropping system

Intercropping is the growing of two or multiple crops, ideally of physiologically and morphologically different types simultaneously at the same land (Maitra *et al*. 2019). Manjunath *et al*. (2018) stated that intercropping is an advantageous crop production method targeted at maximizing productivity and profitability from a unit area and time. Crop intensification takes place over both space and time. According to Eskandari *et al*. (2009), intercropping can be practiced by taking annual crops with annual intercrops, perennial crops with perennial intercrops and annual crops with perennial intercrops. Intercropping is a method that emphasis greater sunlight usage, efficient fertilizer and water utilization, risk reduction and much more exploration of environmental growth variables (Mobasser *et al*. 2014; Ajibola and Kolawole, 2019). During the full or part of the growing period of the component crops, there is intercrop competition. Therefore, it is better to consider crops with greater complementarity, their planting and maturity periods (Fig. 1). The performance of an intercropping system is primarily dependent on these above-mentioned parameters (Maitra *et al*. 2020).

Crop selection

The selection of crops which will show complementarity among them is a key consideration to ensure efficient utilization of available resources (Mathimaran *et al*. 2020; Huss *et al*. 2022). The choice

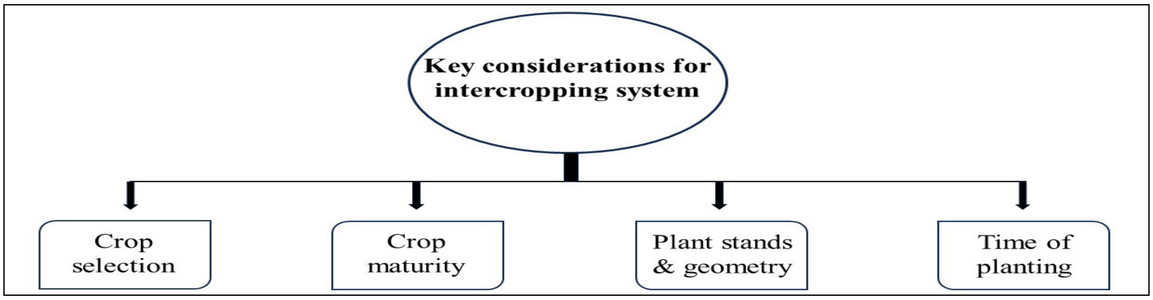

Fig. 1: Considerations for intercropping system

of component crops in a combination, the local agriculture environment and varietal availability are playing a vital role in intercropping profitability (Manasa *et al*. 2020). An appropriate choice of crop species will surely minimize the competition in a mixed stand and enhance resource use efficiency with their complimentary and synergistic effects. The mixed stand of cereals and legumes is very common in intercropping systems, as cereals can benefit from the atmospheric N fixed by legumes (Chimonyo *et al*. 2023; Jena *et al*. 2022). For instance, in pearl millet-based intercropping systems in Southeast Asia and Africa, pigeon pea, Sesbania, soybean, cowpea, green gram, groundnut, moth bean and cluster bean are commonly chosen as the intercrop (Maitra, 2023). Further, pearl millet is a long statured crop; hence, if the legumes chosen are of short height, they must have the quality of shade tolerance (Javanmard *et al*. 2020). Legume species such as green gram, cowpea, black gram, and peanut have minimal adverse effects and are known to be shade-tolerant (Manasa *et al*. 2018).

Crop maturity

The crop maturity is an important factor for selection of crops in an intercropping system (Wolfe *et al*. 2021; Moore *et al*. 2022). In most situations, it is suggested that companion crops in an intercropping system have different peak growth periods, because if not, these component crops would compete for existing common resources (Li *et al*. 2021). As a result, crops with varying maturity times are chosen to provide complimentary benefits (Mugi-Ngenga *et al*. 2023). In pearl millet based intercropping system, it can be considered as the base crop in additive series, hence, either short duration legumes are preferred as intercrops (Iqbal *et al*. 2019). Otherwise, short duration cultivars and hybrids of pearl millet can be chosen and longer duration legumes such as pigeon pea, groundnut etc. can be considered.

Plant stands and geometry

To obtain the highest yield output, it is obvious to maintain proper plant stand as well as geometry. In an additive series of intercropping, base crop proportion remains 100%; however, intercrop ratio may or may not 100%. In a study, Pandit *et al*. (2020) adopted wide row planting of pigeon pea and pearl millet where both the crops obtained their optimum stand establishment in intercropping system as compared to their sole cropping. Sometimes, in a replacement series of intercropping, seed rate can be enhanced or spacing can be reduced to accommodate more plant stand than sole cropping to harness the benefits of intercropping system (Maitra, 2023). In some cases, planting geometry can be changed by preferring paired row arrangement for creation of greater space for intercrops (Bhagat *et al*. 2022).

Time of planting

Pearl millet is a very common cereal crop preferred in intercropping systems, particularly due to its compatibility with legumes. Pearl millet-legumes intercropping system ensures that the competition for essential natural resources does not occur simultaneously between the two crops. Additionally, the mixture of grass-legume combinations enhances the overall quality of the forage in terms of its dietary value. Furthermore, pearl millet has a higher capacity to accumulate carbohydrates, which serve as a source of energy in fodder, from a given unit area (Sairam *et al*. 2023). If the legumes are planted little late in a relay intercropping system, cereals get the fullest advantage of utilizing the available resources (Maitra *et al*. 2023b).

Assessment of pearl millet-based intercropping system in terms of competition functions

Different competition functions have been developed by earlier researchers to measure the benefits of intercropping systems. The concept of the land equivalent ratio (LER) was particularly notable, and the LER was later widely used to measure the benefits of an intercropping system (Willey and Osiru, 1972; Willey, 1979; Beets, 1982). Not only just the LER, but the researchers have formulated some other ideas to explain the competitive interaction and yield benefits through time and space. The following are some of the competition functions, as well as the outcomes of a pearl millet-based intercropping system that showing advantage of mixed stands over the pure stand of pearl millet.

Land equivalent ratio (LER)

The land equivalent ratio (LER) was proposed by Willey and Osiru (1972), and it is defined as the proportionate land area requirement under a pure stand of crop species to provide the same yield as an intercropping at the same management level (Willey *et al.* 1983). The LER may be computed using the following expression in a replacement series of intercropping with two crops at a 1:1 ratio.

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb} = La + Lb$$

For any other case, the following modified formula being used:

$$LER = \frac{Yab}{YaaXZab} + \frac{Yba}{YbbXZba}$$

Where, *Yab* is the yield of "*a*" crop grown in association with "*b*" crop; *Yba* is the yield of "*b*" crop grown in association with "*a*" crop. *Yaa* and *Ybb* represent the yields of "*a*" and "*b*" crops grown in pure stand, respectively. The advantages of the intercropping system are indicated by LER values greater than unity (1.0). (Ofori and Stern, 1987). Table 1 shows the LER values of pearl millet-based intercropping system studied to evaluate the land use benefits of intercropping.

Table 1: Land equivalent ratio (LER) of pearl millet-based intercropping system

Intercropping systems	Ratio	LER	References
Pearl millet + groundnut	1:3	1.54	Ghosh, 2004
Pearl millet + pigeon pea	2:1	1.50	Ansari and Rana, 2012
Pearl millet + green gram	2:1	1.29	Renu *et al.* 2018
Pearl millet + soybean	Binary mixture	1.48	Iqbal *et al.* 2019
Pearl millet + cowpea	2:1	1.28	Chaudhary *et al.* 2020
Pearl millet + black gram	4:1	1.23	Preethi Victor *et al.* 2023

Area time equivalent ratio (ATER)

Hiebsch (1978) proposed the area time equivalent ratio (ATER), which took into account the growth period of crops from sowing to harvest. The ATER is calculated using the formula:

$$ATER = \frac{(RYc \times tc) + (RYp \times tp)}{T}$$

Where, *RY* = Relative yields of crop species '*c*' and '*p*', *t* = duration (in days) for species '*c*' and '*p*', *T* = duration (in days) for the intercropping system. Only the area is considered in the LER, not the time. However, in the ATER, both area and time are taken into account based on crop duration or land occupation by mixed crops. When the ATER value surpasses 1.0, it is having intercropping advantages, similar to LER. Table 2 shows some ATER of pearl millet based intercropping system.

Table 2: Area time equivalent ratio (ATER) of pearl millet-based intercropping system

Intercropping systems	Ratio	ATER	References
Pearl millet + Sesbania	1:1	1.09	Dhaka *et al.* 2014
Pearl millet + soybean	Binary mixture	1.48	Iqbal *et al.* 2019
Pearl millet + green gram	2:1	1.25	Renu *et al.* 2018

Pearl millet equivalent yield (PMEY)

Crop equivalent yield (CEY) is the conversion of crop yields into a single form that may be used to compare crops grown in mixed, intercropping, or sequential cropping systems (De Wit, 1960). The intercrop yield and market price of 'A' and associated intercrops are taken into account when converting yield to base crop (A) equivalent yield. With the following formula, the pearl millet equivalent yield (PMEY) is computed by conversion the yield of intercrop(s) into the yield of 'A' crop, i.e., pearl millet and expressed in t ha^{-1} based on current the prices when the experiment has been conducted.

Pearl millet equivalent yield (PMEY) =

$$\frac{\text{Yield of intercrop}}{\text{Market price of pearl millet}} \times \text{Market price of intercrop}$$

Intercropping combination is advantageous when the base crop equivalent yield (PMEY) is higher in intercropping system than in the sole crop. Table 3 describes the benefits of intercropping in terms of pearl millet equivalent yield (PMEY).

Table 3: Pearl millet equivalent ratio (PMER) of pearl millet-based intercropping system

Intercropping systems	Ratio	PMEY (t ha^{-1})	References
Pearl millet + Pigeon pea	2:1	4.82	Ansari and Rana, 2012
Pearlmillet + mothbean	1:1	3.13	Kiroriwal *et al.* 2012
Pearl millet + cluster bean	1:1	5.24	Bana *et al*. 2016
Pearl millet + green gram	2:1	4.25	Renu *et al*. 2018
Pigeonpea + Pearl millet	1:2	2.00	Vajjaramatti and Kalaghatagi, 2018

In many cases, pearl millet recorded superior growth attributing characters such as plant height, number of tillers etc. in mixed stand compared to their pure stands and it was obtained due to greater level of complementarity among the crop species. Similarly, higher grain yield of pearl millet was recorded by the researchers in intercropping system (Ansari and Rana, 2012; Preethi Victor *et al*. 2023). Legumes in intercropping system with pearl millet is known to check soil erosion, nutrient loss from the soil and depression of weeds (Aasha *et al*. 2017). Also, intercropping system with pearl millet is recognized as more income generating cropping system (Girase *et al*. 2007; Rani *et al*. 2017; Rawat *et al*. 2018).

CONCLUSION

The ancient agricultural method of intercropping provides abundant opportunities for resource use by adding different types of species. In an intercropping system, the crops are selected with the expectation of complementarity among the species in a mixed stand, and correct planting geometry is used to handle two or multiple crops. In India, the pearl millet-based intercropping method is widespread, and research has shown that it is more resource efficient in terms of land and area use efficiency as well as pearl millet equivalent yield. Based on the above findings, it may be concluded that pearl millet cultivators may prefer an intercropping system as a viable alternative for increasing yield output per unit area even also ensuring agricultural sustainability.

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