Review Article

Intercropping options for sustainable minor millet production: A review

ABSTRACT

High population pressure, climate change, stagnant crop productivity, changing food habit and declining natural resources compelled us to go for climate resilient resource conservation technologies to bring sustainability in our crop production. Crop diversification by replacing high input requiring cereals with "nutri- cereals" minor millets in our crop rotations and by following intercropping of minor millets with pulses or oilseeds may be economically profitable, environmentally safe and socially acceptable approach to ensure food and nutritional security of the burgeoning population. This is high time to include millets in our daily diets but millet availability in sufficient amount is big issue. Millets are crops of rainfed and dryland resource poor areas and moreover under the threat of global warming and changed climatic scenario sole planting of millets generally gives less economic returns. So, there is an urgent need for incorporation of the pulses/oilseeds as intercrop in millets production systemto enhance the production to feed the increasing population on sustained basis besides restoring the soil nutritional status and to overcome the environmental stress. But performance of intercropping system depends on proper selections of suitable intercrop, appropriate row ratio combination and proper input management. Very limited research workhas been conductedon intercropping in millets so far but noteworthy informationwas recorded by the researchers, which has been reviewed through a sincere effort here to give critical view about intercropping in minor millets for agricultural sustainability to the farmers, researchers and consumers.

Key words: Intercropping, Minor millets, Sustainability, Crop Equivalent Yield, Land Equivalent Ratio

INTRODUCTION

Presently, agriculture is facing tremendous problem due to climate change and global warming. The main effects of climate change are increase in temperature, uncertainties in rainfall and enhancement of greenhouse gasses emission (mainly carbon-dioxide). As C_4 plants, millets can use enhanced atmospheric CO_2 and convert into biomass (Brahmachari*et al*. 2018). Thus, millets are considered climate smart and nature friendly crops because of high nutritive value and can withstand under warm and drought conditions with short life, low external inputs requirement. tolerance to water and temperatures stress, (Yadav *et al*., 2012; Gupta *et al*., 2017; De Vries *et al*., 2020). Due to climate change, there is a decline in yield, which leads to food insecurity, more attacks of pests and diseases, soil degradation, change in crop schedules, and desertification. The Consultative Group on International Agriculture Research (CGIAR) has opined that millets may additionally play crucial roles in the developing countries like India where food and nutrient security are the key issues (Behera, 2017). Considering, millets as an alternative crop is a better choice and we can say it is the future crop. There is an immediate need to promote the cultivation of millets to ensure food and nutritional security at national level. Due to presence of different anti-oxidants, detoxifying agents and immune modulators in millet grains, these coarse cereals are treated as nutri-cereals (Desai *et al*., 2010; Rao *et al*., 2011;

Itagi*et al*., 2013). Further, these are rich in different minerals and dietary fibres (Saleh *et al*., 2013). These are also important as livestock feed both as grain and forage (Verma and Patel, 2013; Wafula *et al*., 2017). Considering the importance of millets in food and nutritional security, the year 2018 as 'National Year of Millets' at national level and the year 2023 as 'International Year of Millets' was celebrated at global level. Millets are currently grown in 131 countries in over 78 million ha (FAO, 2022) with sorghum and pearl millet accounting for over 90 per cent share at global level. India is the largest grower (with 19% contribution) and producer (20% production) of millets in the world. Share of India in Asia stands at 85% in area and 80% in production of millets. In India, minor millets share an area of 0.44 million ha with a production of 0.35 million tones having productivity of 781 kg/ha and among the minor millets, finger millet occupies larger area under cultivation (Dubey *et al*, 2023). At national level maximum area (89000 hactares) and production (76000 tonnes) of minor millets was reported from Madhaya Pradesh. Top seven countries in the world for pearl millet cultivation are India, Niger, Sudan, Nigeria, Mali, Burkina Faso and Chad. Thus, among the major millets India ranks first in the world with respect to pearl millet cultivation and third in sorghum cultivation. The major millets are Sorghum, Pearl Millet, and Finger Millet covering 95% of the total millet growing area in India and the rest 5% are Little Millet, Foxtail Millet, Barnyard Millet, Proso Millet, Kodo Millet, and Browntop Millet. The most important states for pearl millet cultivation are Rajasthan, Uttar Pradesh and Maharashtra having a total share of 78 per cent. Karnataka alone accounts for more than 2/3rd acreage of finger millet. Chhattisgarh and Madhya Pradesh grow more than 60per cent of small millets.

The demand for food is continuously increasing worldwide due to continuously increasing population. The increasing population of India is not only throwing challenges as higher food productivity but also it is high time that we must check the threats on nutritional security because of drastically changing climatic conditions environmental pollutions. In most of the parts of India, millets are grown as a sole crop during *Kharif* season followed by sequential *Rabi*crop. The area under millet was limited due to low productivity of millets compared to other cereal crops and more focus given to rice, wheat and maizebut during recent period, millets have regained their importance because these of their nutritional benefits and ecological hardiness (Padulosi, 2011; Maitra, 2020). One of the key strategies to obtain sustainable millet production is intercropping. Intercropping fulfills the objectives of ecological balance, effective utilization of nutrients and water, risk reduction, increasing the quantity and quality and reduce yield damage to pests, diseases and weeds (Udhaya Nandhini and Somasundaram, 2020 and Sharmili *et al*, 2021). Growing of two or more crops not only creates crop diversity, but also makes favourable ecology for the predators (Nicholls and Altieri, 2013). In other words, it may be stated better ecosystem service is created by intercropping system which leads agriculture towards sustainability (Maitra, 2020).Growing of a single crop in a year or cereals as sole crop is not so much remunerative in present scenario of agriculture to fulfil the diverse need of rapid growing population and malnutrition. There is an urgent requirement for incorporation of the pulses/oilseeds in millets production system to stabilize the production to feed the increasing population besides restoring the soil nutritional status and to overcome the environmental stress.Furthermore, small millets are compatible for polyculture as mixed and intercropping, thus offer sustainable usage of available resources, food, nutrition and livelihood security to small holders in drylands (Shashidhar *et al*., 2000; Kiwia*et al*., 2019; Opole, 2019). While selecting crops for intercropping system, complementarity among the species cultivated is very much important aspect to be considered for increasing crop yields (Ngwira *et al.*, 2012; Pappa *et al*., 2012). Very limited research work has been carried out on intercropping in millets so far and noteworthy information on various intercropping indices to evaluate biological potential, relative competitiveness, land use and economic efficiency weredrawn by the scientists (Dhaka *et al*, 2015), which has been reviewed here for understanding the benefits of intercropping system in millets as follows.

Intercropping in Fingermillet

Dass and Sudhishri (2010) recorded the highest net returns (Rs. 9,665/ha) and benefit cost: ratio (1.00) obtained with finger millet + pigeonpea (6:2 ratio). Highest LER (1.34) was recorded from Finger millet + pigeonpea (5:2 and 6:2), which was significantly higher than Finger millet + black gram at all the row ratios except at 5:2. Combined yield of finger millet and legumes was more and both the combinations of finger millet + pigeon pea and finger millet + black gram produced more finger millet equivalent yield (FMEY) than sole finger millet (Adhikari *et al*., 2018). Kumar and Ray(2020) found that Finger millet + Black gram (4:2) combination recorded significantly higher finger millet grain equivalent yield (4233 kg/ha), highest net return of Rs. 68776/ha and benefit cost ratio of 2.82. While maximum yield of finger millet (2010 kg/ha) was recorded when intercropped with black gram in 6:2 ratio. Finger millet + haricot bean improved yield stability and economic return in north-western Ethiopia (Bitew *et al*., 2020). In Ethiopia, the mixed cropping of lupine and finger millet at the 50:100 and 75:100 seeding proportion had a greater yield advantage compared to sole cropping of either lupine or finger millet (Bitew, 2014). Regardless of the planting method and ratio, finger millet was more compatible with haricot bean than lupine (Bitew *et al*., 2019). The improved cropping systems including finger millet + pigeon pea in 8-10: 2 or finger millet + field bean in 8: 1 for Karnataka and Tamil Nadu and finger millet + field bean in 6 : 2 row proportion for Bihar; finger millet + soybean (9:1 crop mixtures) for Garhwal region of Uttarakhand; finger millet + mothbean/blackgram (4:1) for Kolhapur are recommended (Chapke*et al*, 2020). Gowda *et al*., 2004 at Coimbatore showed that intercropping determinate type of field bean with finger millet variety Co 11 in 8:1 row proportion was a remunerative choice (Rs. 13360 NMR ha^{-1}). Jakhar *et al.* (2015) worked on strip cropping of finger millet + groundnut and observed the above combination at 6:4 row ratio showed the highest value in terms of FMEY, net income and benefit: cost ratio. Finger millet + pigeon pea (8-10: 2) or finger millet + field bean (8: 1) is quite popular among the farmers of Karnataka and Tamil Nadu, but in Bihar, intercropping combination of finger millet and field bean (6: 2) was noted to perform well. For Gadhwal region of Uttarakhand finger millet + soybean (90:10 percent crop mixtures) and for Kolhapur region of Maharashtra finger millet + moth bean/black gram with row ratio of 4:1 were observed beneficial. Among the intercropping systems, significantly higher available nitrogen, phosphorus, potassium and sulphur was recorded in 2:1 row ratio of soybean + finger millet and it was on par with 2:1 row ratio of soybean + foxtail millet (Manjunath *et al*, 2023). Maitra *et al*. (2000) worked in the red and lateritic belt of West Bengal and opined that intercropping of finger millet in combination with pigeon pea and groundnut (4:1) recorded more yield and resource use efficiency (as LER) when compared to pure stand of finger millet. Mitra *et al.*, (2001) also attributed that finger millet produced more yield under intercropping with pigeonpea compared to grown as sole cropping. Manjunath and Salakinkop (2017) noted greater resource use efficiency in terms of LER when soybean intercropped with finger millet at 2:1 and 4:2 proportions and the LER values were 1.45 and 1.47 which were more than unity, showing advantages of intercropping. Murali *et al*. (2014) reported that intercropping of finger millet + pigeonpea (transplanted) gave maximum net returns Rs.26,218 / ha with benefit: cost ratio of 2.49. Murali *et al*. (2014) reported that intercropping of finger millet + pigeonpea (transplanted) gave maximum net returns Rs.26,218/ha with benefit: cost ratio of 2.49. Nigade *et al.* (2012) revealed that the black gram or moth bean as an intercrop in 8:2 or 4:1 row proportion in finger millet increased the grain yield to the tune of 42 to 57 per cent over sole cropping. Pavankumar *et al* (2021) recommendedintercropping of Fingerl millet + Red/black/green gram 6 or 8:2 or soyabean 4:1 ratio.Padhi *et al*., (2010) reported that intercropping system of pigeon pea (UPAS-120) + finger millet (Bhairabi) at 2:4 row ratio recorded higher LER (1.42) and found most economical as compared to pigeon pea (UPAS-120) + finger millet (PR-202) in 2:4 row ratio. Patil (2003) reported that finger millet + pigeon pea intercropping at 4:1 ratio recorded the highest land equivalent ratio (1.48) indicating 48% more land use efficiency over the sole cropping of finger millet. Pradhan *et al.* (2014) reported that the economics of intercropping on finger millet with pigeon pea combination was found to be the best in obtaining highest net returns of Rs. 36444 and Rs. 21384 ha^{-1} in respective years (2005 and 2006) and also highest (20.57 and 17.64 q ha^{-1}) yield was recorded in finger millet + pigeon pea intercropping, followed by horse gram and black gram and minimum was in finger millet + niger intercropping. Pradhan *et al*. (2014) in his studies in finger millet found that when finger millet was intercropped with soybean at 4:1 ratio recorded higher LER (1.66 and 5.69, respectively). Prakash *et al*., (2005) reported that finger millet was intercropped with wheat and pigeon pea (4:1 and 8:2) which resulted to higher finger millet equivalent yield under intercropping (6.49- 6.56 t/ha) than under sole cropping (3.37 t/ha). Higher net returns (Rs. 23277/ha) and benefit-cost ratio (5.90) were recorded under strip cropping of finger millet + pigeon pea as compared to sole crop of finger millet [Net returns (Rs. 14854/ha)] (Ramamoorthy *et al*., 2003). Ramamoorthy *et al*., (2003) reported that finger millet + determinant type of field bean intercropping recorded higher LER (1.48) as compared to finger millet + field bean intercropping system in 8:2 row ratio (1.45) and sole crop of finger millet (1.00) at Coimbatore. Ramamoorthy *et al.* (2004) reported higher net return from pigeonpea and finger millet intercropping system obtained at 2:4 row ratio.Sharmili *et al*, 2021 and Padhi *et al*. (2010) revealed that raising of finger millet and pigeonpea in 4:2 ratio under rainfed condition during the rainy season proved most productive, economically viable, and energetically efficient than their sole plantings. Shivaraj (2015) at Dharwad reported that, the highest GPEY (groundnut pod equivalent yield) was recorded with finger millet (2,916 kg ha^{-1}) in 4:2 row ratio. Singh and Arya (1999) at Uttrakhand observed that finger millet and soybean mixed cropping system (9:1 seed mixture) recorded higher LER (1.35) as compared to finger millet + rice bean (1.21) and finger millet + rajma mixed cropping system and sole crop of finger millet. Finger millet + Frenchbean (3:1) is found a profitable intercropping system in the mid hills of NorthWest Himalaya. Intercropping of soybean/urd bean/pigeon pea/rice bean with finger millet accounted for higher economic returns than other system of finger millet with field bean/cowpea/green gram (Shalini *et al*, 2019). Thorat *et al*. (1986)and Yadav (2018) highlighted greater resource use efficiency in terms of enhancement of the LER by finger millet and green gram or pigeon pea intercropping system and increase in productivity as finger millet equivalent yield that harnessed manifold.

Intercropping in Foxtail millet

Anishetra and Kalaghatagi (2021) revealed that sesame + foxtail millet (3:3) intercropping system recorded higher seed yield of sesame (255 kg ha^{-1}), while higher LER (1.33), ATER (1.28),grain yield of millets (1337 kg ha^{-1}) and net returns (Rs. 36875/ha) was recorded with sesame + foxtail millet (2:4) intercropping system. The highest sesame equivalent yield was recorded with sesame + foxtail millet of 2:4 (703 kg ha^{-1}) and it was on par with sesame + foxtail millet of 3:3 (658 kg ha^{-1}). Basavarajappa*et al.* (2003) also revealed that under shallow alfisolsSignificantly higher foxtail millet equivalent (5270 kg ha^{-1}) was recorded in foxtail millet + pigeon pea (100%) followed by foxtail millet + mesta (100%) with 3053 kg ha^{-1} and concluded that inter cropping system of foxtail millet + pigeon pea (100%) is seems to be profitable in northern transitional zone of Karnataka. Biradar *et al* (2020) reported that Significantly higher Pigeon pea seed Equivalent yield (1152 kg/ha and 1146 kg/ha), net returns (Rs. 44419/ha and Rs. 43600/ha), BC ratio (2.93 and 2.84) and LER (1.16 and 1.06) was recorded in pigeon pea + foxtail millet (1:2) intercropping system for 2017 and 2018, respectively and which was at par with sole pigeon pea cropping system. Chapke*et al* (2020) from ICAR-Indian Institute of Millets Research, Hyderabad recommended Foxtail millet + groundnut (2:1 ratio), foxtail millet + cotton (5:1 ratio) and foxtail millet + pigeon pea (5:1 ratio) intercropping for benefit of Foxtail millet farmers. Gurunanda Rao(1986) reported that the highest total yield of 2770 kg ha^{-1} was recorded in foxtail millet pigeon pea paired row (15-35 cm) followed by foxtail millet + castor (1730 kg ha^{-1}) and foxtail millet + cotton (1270 kg ha^{-1}) which was more profitable than the local practice of 5:1 row proportion. In another study at Hanumanamatti, the intercropping of sesamum with foxtail millet in 2:4 row proportion was found profitable. Himasree*et al*. (2017) concluded that more gross and net incomes and benefit-cost ratio were obtained with the sowing of foxtail millet + pigeonpea (5:1) with sowing during first fortnight of August. LER, ATER and foxtail millet grain equivalent yield were more with the intercropping system of foxtail millet + pigeonpea (5:1) sown during the first fortnight of August. Kiranmai *et al* (2021) revealed that significantly higher millet grain yield (4498 kg/ha) and highest gross returns (89991 Rs./ha), net returns (64441 Rs./ha) and B:C (3.52) ratio were recorded with Foxtail millet + Redgram in 6:1 ratio followed by foxtail millet + Redgram in 4:1 ratio.Manjunath and Salakinkop (2017) and Manjunath *et al*. (2018) showed that intercropping of soybean + foxtail millet at row proportion of 2:1 and 4:2 recorded that advantageous LER (1.49 and 1.50 respectively) and higher B:C ratio (2.39 and 2.45 respectively). Manjunath *et al*. (2018) reported that superiority of intercropping pigeonpea + foxtail millet (1:2) as higher net returns with benefit cost ratio of 3.79 were recorded over sole cropping. Manjunath *et al*. (2018) showed that intercropping of soybean + foxtail millet at row proportion of 2:1 and 4:2 recorded that advantageous LER values. Manjunath *et al*. (2018) from another study reported that superiority of intercropping pigeonpea + foxtail millet (1:2) as higher net returns (11,1457/ha) and benefit cost ratio of 3.79 were recorded over sole cropping. Pavankumar *et al* (2021) recommended intercropping of Foxtail millet + G.nut/cotton/red gram 5:1 ratio.Sharmili *et al* (2021) and Manjunath *et al* (2023) reported that significantly higher soybean seed equivalent yield was recorded in 4:2 row ratio of soybean + foxtail millet (2,334 kg ha^{-1}) and it was at par with 2:1 row ratio of soybean + foxtail millet (2,310 kg ha^{-1}).Shwethanjali*et al* (2018a) reported that significantly higher plant height, number of branches, leaf area and total dry matter accumulation were recorded in intercropping of groundnut + foxtail millet with 6:1 row proportion. Among the intercropping treatments, groundnut + foxtail millet (6:1) recorded significantly higher groundnut pod(1,744 kg ha^{-1}), haulm (2,194 kg ha^{-1}) and groundnut equivalent yield (1,876 kg ha^{-1}) and thus registered more land resource use efficiency as marginal increase of LER value (1.14) and higher B:C ratio (2.23) as against B:C ratio of sole groundnut of 2.14 and sole foxtail millet of 1.23.

Intercropping in Little millet

Anishetra and Kalaghatagi (2021) reported that sesame equivalent yield (667 kg ha^{-1}) recorded with sesame + little millet (2:4) was at par with sesame + foxtail millet / proso millet (2:4). Chapke*et al* (2020) from ICAR-Indian Institute of Millets Research, Hyderabad and Maitra and Shankar (2019) recommended that in Orissa, Little millet + black gram in 2:1 row ratio; in Madhya Pradesh Little millet + Sesamum/soybean/pigeon pea in 2:1 row ratio and in Southern Bihar Little millet + pigeon pea in 2:1 row ratio are very common intercropping systems to get sustainable yield of Little millet.Dubey and Upadhyaya (2001) reported that short duration littlemillet (JK-8) intercropped with medium duration pigeonpea (No.148) in 2:1 row ratio gave higher little millet GEY (1903 kg ha^{-1}), with highest Net monetary return (Rs.4335 ha^{-1}) and B:C ratio (1.91).Keerthanapriya *et al* (2019) reported thatsignificantly higher little millet Grain Equivalent Yield (2083 kg ha^{-1}) was recorded in little millet + small onion intercropping system and it was followed by little millet + cowpea (1742 kg ha^{-1}), while highest LER (1.32) was recorded in little millet + blackgram. Theyconcluded that little millet + blackgram may be the best intercropping system butlittle millet + greengram/ cowpea/small onion intercropping may also be recommended as an alternative option over the sole little millet crop.Kiranmai *et al* (2021) concluded that highest Millet grain Equivalent Yield (3366 kg/ha) was recorded with little millet + redgram in 6:1 ratio, which was at par with little millet + Redgram in 4:1 ratio (3120 kg/ha) and recommended intercropping systems of little millet with redgram in 6:1 to obtain higher yields.Little millet and pigeon pea intercropped in 6:2 row ratio produced significantly higher dry matter production, ear length, grain weight, grain yield of little millet and pigeon pea as compared to their sole cropping (Kumar *et al*., 2008).Higher little millet equivalent yield was recorded in intercropping of little millet and pigeonpea in 6:2 row ratio with or without horsegram sequence as compared to rest of the treatments (PrasannaKumar *et al*., 2008).Patil *et al*., 2010 at Dharwad, Karnataka indicated that little millet + pigeonpea intercropping system of 5:1 row proportion recorded more dry weight, length of ear, grain weight and little millet grain yield,but the highest little millet equivalent yield (LMEY) was recorded with 4:2 row ratio. Prajwal and Kalaghatagi (2018) reported that higher land equivalent ratio (LER) was found in castor + little millet (1.58). Manjunath *et al* (2023) reported Significantly lower grain yield of millets was recorded in 2:1 row ratio of soybean + little millet (1,177 kg ha^{-1}) compared to rest of the treatments. The intercropping combination of soybean + little millet (4:2) resulted in higher resource use efficiency as LER (1.39) compared to pure stands of soybean and B:C ratio was 1.95 which clearly indicated advantage of intercropping with little millet (Manjunath and Salakinkop (2017). Pavankumar *et al* (2021) recommended intercropping of Little millet + Black/Red gram/ Soyabean/Sesamum in 2:1 ratio. Sharmili *et al* (2021) and Sharmili and Parasuraman (2018) observed that the highest little millet equivalent yield was recorded with 4:2 row ratio of little millet and pigeonpea followed by 2:1, 6:2 and 3:1 row ratios. Relay cropping of little millet + horse gram recorded significantly higher little millet equivalent yield than that obtained under little millet alone. Sharmili and Parasuraman (2018)also concluded that growing of little millet and pigeonpea in 6:1 row ratio with horsegram or mothbean in sequence have been found superior over other intercropping systems and also growing sole crop of little millet alone.Shwethanjali*et al.*,(2018b) reported that Intercropping combination of groundnut and little millet (6:1) assured better resource use efficiency as LER (1.13) than pure stands of either groundnut or little millet and more B:C ratio of 2.16and recorded groundnut equivalent yield (1,822 kg ha^{-1}) which was at par with groundnut + little millet/finger millet under same row ratio.Shalini *et al* (2019) and Sharmili and Manoharan (2018) reported that the yield attributes of little millet like number of productive tillers per hill and test weight was found to be increased when intercropped with pigeon pea at 6:1 ratio and thus intercropping little millet and pigeon pea at proportions of 6:1 or 6:2 is beneficial.Shivaraj (2015) reported higher area time equivalent ratio (ATER) (1.17) in 4:2 row ratio of groundnut + little millet intercropping systems, while groundnut pod equivalent yield recorded with Groundnut + little millet (2,581 kg ha^{-1}) was significantly lower than Groundnut finger millet/ foxtail millet in 4:2 row ratio.Sharmili and Manoharan (2018) reported that when little millet intercropped with green gram at 8:2 ratio, recorded higher gross return (Rs. 57,036/ha), net return (Rs. 35,531/ha) and benefit-cost ratio (2.65) followed by intercropping of little millet with blackgram and small onion compared to other intercrops. Intercropping of little millet with greengram recorded 15 per cent increase in net return over the sole crop of little millet.Sharmili *et al*. (2019) stated that intercropping little millet with pigeonpea in 6:1 row ratio followed by sequential cropping of horsegram recorded higher grain and straw yield along with higher gross return (Rs. 86,379 ha^{-1}), net return (Rs. 48,209 ha^{-1}) and benefit cost ratio (2.26). She also mentioned that intercropping little millet and pigeon pea at proportions of 6:1 or 6:2 is beneficial. Shashidhar *et al*. (2000) reported that higher finger millet equivalent yield was recorded with in little millet + pigeonpea (4:2) compared to 3:1 and 5:1 row proportions.Little millet grown along with small onion and radish recorded higher grain equivalent yield followed by intercropping of little millet with pulses (Sharmili and Manoharan, 2018).

Sharmili and Yasodha (2021) and Sivagamy *et al*. (2020) presented that higher grain (652 kg/ha) and straw yields (1676 kg/ha) were recorded with little millet + pigeonpea at 8:2 ratio followed by sequential crop of blackgram and it was at par with little millet + pigeonpea followed by horsegram sequence. Sharmili *et al* (2023) concluded that the yield attributes of little millet like number of productive tillers per hill and test weight is found to be increased when intercropped with pigeonpea at 6:1 ratio. Significantly higher value of LER (1.46), highest gross return (Rs. 86,379/ha), net return (Rs. 48,209/ha) and benefit cost ratio (2.26) were observed with little millet + pigeonpea - horsegram (6:1),which was statistically at par with little millet + pigeonpea - mothbean (6:1). Vajjaramatti and Kalaghatagi (2016) reported significantly higher area time equivalent ratio (ATER) in pigeon pea + little millet (1.64) in 1:2 row ratio compared to sole crops. Keerthanapriya *et al* (2019) reported that significantly higher little millet Grain Equivalent Yield (2083 kg ha^{-1}) was recorded in little millet + small onion intercropping system and it was followed by little millet + cowpea (1742 kg ha^{-1}), while highest LER (1.32) was recorded in little millet + blackgram. They concluded that little millet + blackgram may be the best intercropping system butLittlemillet + greengram/cowpea/small onion intercropping may also be recommended as an alternative option over the sole little millet crop.

Intercropping in Proso millet

Anishetra and Kalaghatagi (2021) reported that intercropping of sesame with proso millet in 2:4 row ratio recorded net returns (Rs. 32314), B:C (3.41) and LER (1.27), which were 49.6,27.2 and 27 percent higher than sole proso millet planting, respectively and it was more profitable over sesame + proso millet intercropping in 1:2/3:3 row ratio.In Bihar and Uttar Pradesh generally, intercropping of Proso millet + green gram in 2:1 ratio is in practice and in Western Bihar, Potato - Proso millet cropping sequence is profitable(Chapke*et al*., 2020). The yield enhancement in intercropping can be achieved by altering light distribution as observed in proso millet + mung bean (2:4) facilitating greater resource use efficiency, photosynthate production and proper conversion to sink (Gong *et al*., 2019). The grain yield of proso millet when intercropped with mung bean was improved by 6.8–37.3% compared with the pure stand of proso millet in China (Gong *et al.*, 2019) and this was achieved delay in the proso millet flag leaf senescence in intercropping which helped in increasing grain yield of millet. Gong *et al* (2020) reported that the mean yields in intercropping systems of Proso millet + Moong bean 2 + 2, 4 +2, 4 + 4 and 2 + 4 were greater by respectively 17.1%, 6.8%, 20.1%, and 37.3% than that in sole Proso millet. The LERs for the intercropping patterns were all greater than unity (>1), maximum LER was obtained with Proso millet + Moongbean (2+4) i.e., 1.86 in first year and and 2.22 in second year of study. Milenkovic *et al.* (2019) reported that 1:1 ratio of soybean and proso millet in intercrop resulted in high biomass yield in Belgrade, Serbia. Manjunath *et al.* (2018) mentioned that intercropping pigeonpea + proso millet (1:2) resulted in higher net return and B:C ratio over sole cropping. Pavankumar *et al* (2021) recommended intercropping ofProso millet + Green gram 2:1 ratio.

Intercropping in Barnyard millet

Anonymous (2000) and Maitra (2020) concluded that crop mixtures of barnyard millet 90% and soybean 10% was found feasible system. The next best is found to be the mixed cropping of barnyard millet with amaranths (90:10 by weight). Intercropping of barnyard millet + Red gram (6:1) was the utmost remunerative intercropping system for increased overall productivity of the system. Anonymous (2013) concluded that when barnyard millet was intercropped with amaranthus (90:10 by weight) at Ranichauri during 2017, the Barnyard millet grain equivalent yield (2308 kg/ha) and Benefit cost ratio

(3.02) was significantly higher than in other treatments. Chapke*et al*. (2020) mentioned that in Uttaranchal barnyard millet and rice bean (4:1) intercropping system is recommended.Humeshwar*et al.*(2022) reported that intercropping of Barnyard millet with Pigeonpea in 4:1, 6:1 and 8:1 row ratio were proved more economical than sole Barnyard millet and these were recorded with B:C 2.65, 2.68 and 2.67 with a margin of 9.9, 11.2 and 10.7 percent, respectively over sole barnyard having B:C (2.41).Kumar *et al* (2008) and Shalini *et al* (2019) recommended intercropping of Barnyard millet + Soybean/rice bean (9:1). Pavankumar *et al* (2021) recommended intercropping of Barnyard millet + ricebean in 4:1 row ratio. Singh and Arya (1999) reported that the grain yield of barnyard millet was higher in pure stand compared to crop mixture, but combination of barnyard millet and soybean (seed mixture of (90:10 percent recorded higher LER (1.45) and barnyard millet equivalent yield. Sukanya *et al* (2022) reported that Intercropping of either barnyard millet + horse gram or barnyard millet + rice bean/Niger was better inter cropping system and barnyard millet+ rice bean (4:1) under rainfed conditions produced higher grain yield in intercropping system with 50 per cent N.

Intercropping in Kodo millet

Sufficient research work has not been carried out on intercropping of Kodo millet. However, on the basis of available literature, some information is presented here. Chapke*et al* (2020) recommendedintercropping of Kodo millet + Pigeon pea in 2:1 ratio In Madhya Pradesh. The intercropping of Kodo millet + Green gram/black gram combination in 2:1 ratio and Kodo millet + Soybean in 2:1 ratio is also advised to practice. Dubey and Shrivas (1997) postulated that higher kodo millet equivalent yieldand gross and net monetary returns, Rs. 7403 and 3397/ha, respectively with an additionalreturns of Rs. 904 ha^{-1} over the sole crop of kodo millet were obtained in intercropping of kodo millet and pigeonpea in 2:1 planting ratio.Mahajan(2016) found that highest and lowest values for Kodo millet equivalent yield were obtained with pigeon pea intercropping and intercropping with guar, respectively. Among intercropping systems, Intercropping of Kodo millet +pigeon pea recorded higherB:C of 1.42.Humeshwar*et al* (2022) reported that intercropping of Kodo millet with Pigeonpea in 4:1, 6:1 and 8:1 row ratio were proved more economical than sole Kodo millet and these were recorded with B:C 3.33, 3.31 and 3.08 with a margin of 14.8, 14.1 and 6.2 percent, respectively over sole Kodo millet having B:C (2.90). Kumar *et al* (2008) and Shalini *et al* (2019) reported that intercropping of Kodo millet + black gram/ pigeon pea (4:1) is beneficial. Pavankumar *et al* (2021) recommended intercropping of Kodo millet + Soyabean/Red/Black/Green gram 2:1 ratio.Shalini *et al* (2019) recommended Intercropping of soybean / urd bean / pigeon pea/rice bean with Kodo milletto get higher monetary returns.

CONCLUSION

To ensure the food and nutritional security under the threat of global warming and climate change conditions, we have to go for some climate smart and effective crop technologies by following crop diversification and intercropping.Due to multifaceted benefits like greater resource use, better soil health and agricultural sustainability, inclusions of millets and intercropping may be best option to address all current challenges and meets the world’s current and future food needs on sustained basis. Minor millets are ecologically hardy crops which can provide food and nutritional security. The sole planting of minor millets is not so remunerative because of low productivity compared to other cereal crops and hence this situation can be overcome by following intercropping in millets. On the basis of reviewed literature, it can be concluded thatfor Finger millet, the intercropping of finger millet + pigeon pea (8-10: 2), finger millet + field bean (6-8: 1-2), finger millet + soybean (9:1) and finger millet + mothbean/blackgram (4:1), while for Foxtail millet, Foxtail millet + groundnut (2:1), foxtail millet + cotton (5:1) and foxtail millet + pigeon pea (5:1) intercropping arehighly beneficial. For Little millet intercropping, Little millet + black gram (2:1), Little millet + Sesamum /soybean/pigeon pea (2:1), Little millet + pigeon pea (2:1)are successful, while Proso millet + green gram (2:1), barnyard millet + rice bean (4:1), Kodo millet + Pigeon pea (2:1)andKodo millet + Green gram/black gram/ Soybean (2:1)are also advised to farmers to enhance their economic returns and yield.

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